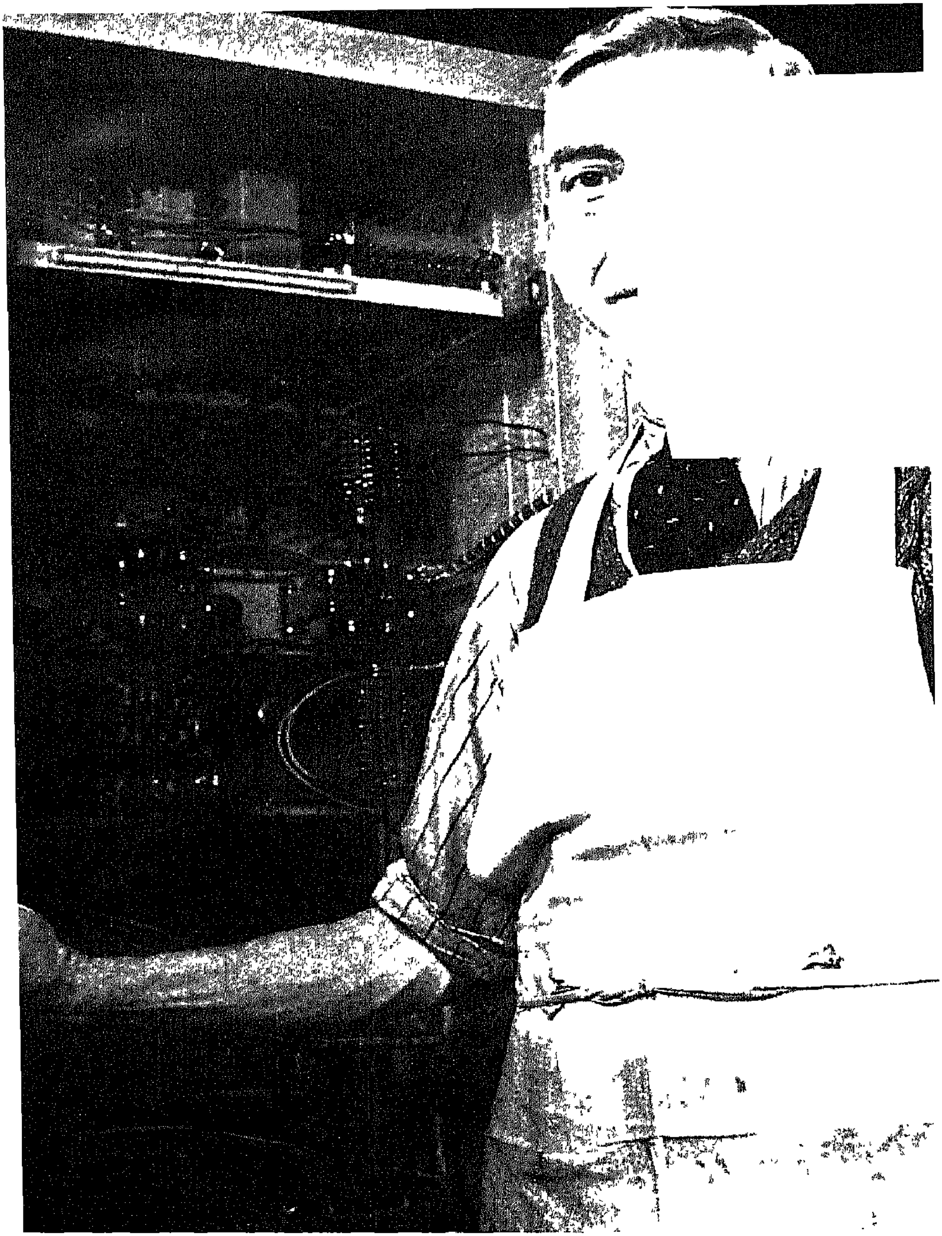
MARCONI

1939 - 1945

AGE
A Veteran of the Senior Service



AGE
and a Veteran of Industry

"The achievements of British Science and Technology during these last years of total War have been outstanding. . . . With relatively limited resources—and these strained to the utmost—we may, nevertheless, claim to have outmatched our enemies in every vital respect."

H.M. THE KING,

October 25, 1945.

MARCONI
1939 - 1945

A WAR RECORD

by

George Godwin

CHATTO & WINDUS

LONDON
1946

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MARCONI

Man by the mountain wall,
On plains or over the spray,
Lifted his voice to call
And was heard no further away
Than any voice of them all.

As soon as night began
Creatures that fly or prowl
Would raise the cry of their clan,
Wolf, lion or owl,
And were heard as far as man.

Marconi came to birth
And before he left us again
Our voice was of greater worth,
For we speak and are heard plain
At the very ends of the earth.

LORD DUNSANY.

DEDICATION

This War Record is offered as a Tribute to the men and women of the Three Fighting Forces, the Merchant Navy, and the Fishing Fleets by some who served them in workshop, office and laboratory, where were forged those invisible weapons that overcame Space and gave eyes to those who fought evil in darkness. . . .

H. W. GRANT, Admiral.

Chairman,

MARCONI'S WIRELESS TELEGRAPH CO., LTD.

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Photographs by M.O.I., Marconi Company and John Stone

I

THE BATTLE OF FRANCE

THE BLUE TRAIN

On 6th October, 1939, a member of the Designs Department in the Marconi Company's Chelmsford Works hurried into the Shops and thrust a paper into the hands of the Works Manager.

"This is a red-hot job for the Air Ministry," he announced, "Now, go to it."

Scribbled in pencil on the paper—a Works Note—were these words: *Install S.W.B.8 short wave transmitter equipment in coaches to design instructions.*

The Works Manager thus faced with the urgencies of a "crash" job, returned a laconic "O.K." and began at once picking a team of men suited to carry the work out at maximum speed, and with the sort of efficiency that is the fruit of skill and natural aptitude wed to practice.

Those were the early days of the War when Hitler, temporarily sated by his blitz conquest of Poland was putting out peace-feelers to a Great Britain reacting soberly to the Royal Proclamation extending the call-up age to twenty-two. Those were the days when the tempo of war, and its tensions, were discernible to all save those impervious to the logic of events. They were, in a word, the days before the great battle broke in France, when as yet only the shadow of defeat lay over our land.

While the foreman was still hand-picking his team, a string of rakish-looking luxury motor coaches were being driven into the yard on the south side of the camouflaged works.

They represented the fruits of a London-wide search by an official of the Company and an Air Ministry officer armed with plenary power of requisition.

Not many minutes later a group of men came into the yard from the Works, swung into the coaches and began ripping out their upholstered and chromium-plated interiors.

The "crash" job was under-way.

CRASH JOB NO. 1

Recalling the occasion at a later date, the foreman of the job said:

"Normal practice is for a job to be carried out from drawings prepared for us by the Designs Department, and these indicate clearly every detail.

"But there was no time for that. So our instructions were just word-of-mouth as we went along. And it was 'Do this' and 'Do that', and 'Tear that out' and 'Shove this over' and 'Knock that away'. And we went to it."

The precise nature of the task set this handful of workmen under the engineers of the Design Department was the conversion of the ten luxury motor-coaches into two heavy mobile field stations, complete with transmitter, power plant, central telegraph office, receiver and accommodation coach.

It was a job that, working normal hours, at normal speed, from full drawings, might have been completed with credit to all concerned in from four to five months.

Working a twenty-four hour day, with some men putting in a twenty-four-hour shift now and then, and one man sustaining a continuous forty-eight-hour shift, the first conversion was completed by 12th October; the second five days later.

On that day, a group of exhausted, sleep-drunk men watched the R.A.F. drivers take over those transformed vehicles that combined, with their suggestion of power and efficiency, the promise of speed.

And someone said jestingly: "Ah, there goes the Blue Train!"

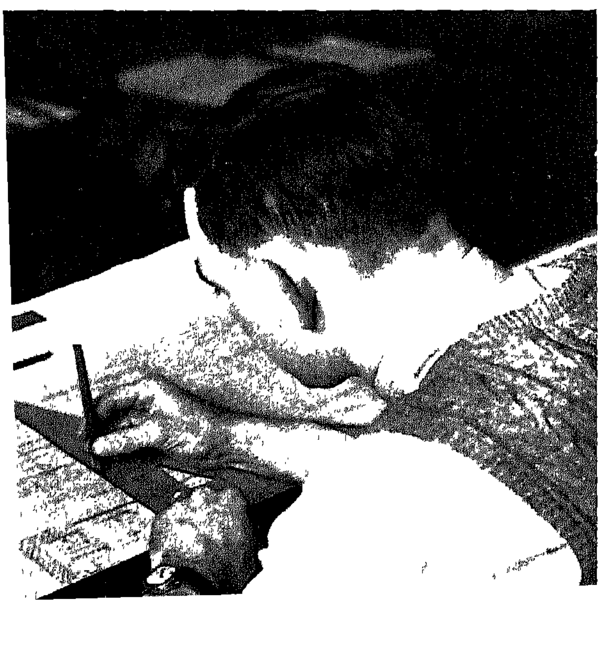
And the name stuck.

DUNKIRK

This was the first of many a "crash" job to test the resources of the Company in men, materials and machines that were to come in the years ahead. And it is as the first of the many that it is best remembered.

The full story of the subsequent history of the Blue Train is unlikely ever to be told; for the men who drove those vehicles throughout the ensuing weeks of calamity in the great race for Dunkirk and the sea have left no record of those days.

What is known is that throughout the days and nights of chaos and military disintegration that followed the Battle of the Bulge, the two Blue Trains were for many days the sole means of communication between the British Army, fighting its way out to Dunkirk, and an anxious War Office and Cabinet in London.



In the Drawing Office

Throughout that terrible phase, the two Blue Trains, with their crews of twenty men, maintained, day-and-night, uninterrupted wireless communication between London and the moving headquarters in the field, transmitting thirty thousand words a day. As one train moved south and the other north, they halted in turn to handle the communications, working twelve hour shifts, thus assuring the essential twenty-four hour service.

At Calais, its task completed, one Blue Train, fully equipped, and in full working order, was driven over the cliffs into the waters of the Straits of Dover.

The other train, in due time, reached Marseilles, and there, with the same object, was broken up.

Some months later, a single S.W.B.8. transmitter was unloaded at the Chelmsford Works. It was somewhat dilapidated, and its Marconi-grey painted brass case was pock-marked from the blows of a pick-axe.

A small group of men examined the transmitter curiously, and, no doubt, with mixed feelings. In it they saw, and recognized, all that was left of the two Blue Trains that had gone so proudly out the yard but a few weeks before.

This was the first of the 380 war-time commercial-vehicle conversions made at Chelmsford, each of which was equipped with S.W.B.8 or S.W.B.11 units. They were mostly used by the Army, and often on gun sites for jamming the enemy. It was an output equivalent to one complete conversion every nineteen hours throughout the War.

But only one more "train" went out of the Works yard. It was made up of seven Bedford-Scammell vehicles converted into a mobile transmitting and receiving station.

It was christened The Golden Arrow.

HOW THE COMPANY MADE READY

The Marconi Company had certain advantages when war broke out. It had been founded in 1897, by Marconi, whose brilliant pioneer work in the field of wireless transformed a laboratory toy into a revolutionary method of communication and laid the foundations upon which has been reared the vast edifice of electronic research and development as we know it to-day.

The Company consequently possessed very wide experience of this particular application of science to the work of the world. Its personnel included brilliant engineers, physicists, mathematicians and chemists, and its labour force included many men most highly skilled in work calling for the finest craftsmanship.

Next, the Company had an organization which had evolved in harmony with the advance of science and invention and possessed, by reason of its plasticity, the capacity for future growth and adaptation.

Thus the War involved it in no internal upheaval, but merely produced a violent increase in the tempo of scientific research, development and manufacture.

Latent here were the many devices and inventions that were to come to

fruition during the War for the support of our fighting Services and to the confusion of our enemies.

The range was very wide, and always widening. It included bomber and fighter equipment, gear for battleships and little ships, U-boats, sea-mine and enemy aircraft counter-measures, tactical and strategical wireless communications, and powerful transmitters for the world-wide broadcast voice of freedom.

It included, too, Radar equipment and a whole range of inventions and devices; and last, that considerable contribution made through the services of scientific and technical men who went to work in and out of uniform for the purpose common to all.

Thus, when war broke out the Company's plant and personnel simply took up a production load for which they had been groomed over a number of years from the very nature of their work.

LOOKING AHEAD

One day, early in 1938, the Chairman sent for the Works Manager. He said: "I want you to consider all measures for the maintenance of power—unlimited and assured power—against the emergency of war. And I want you to make all provision for emergency communications, and for proper shelter accommodation against the same contingency."

By the end of 1938, the Works Engineer was able to report: "We now have electrical plant independent of the grid to provide 80 per cent. of our normal load."

He was also able to report a flourishing Company Fire Brigade (presently to become locally famous) at double strength and doing weekly fire drills.

In May, 1939, when war was seen to be inevitable, a control centre into which some two thousand tons of concrete were poured took shape in the Works yard. It remains there, with its three-feet-six inch walls and seven-feet-six inch roof: and it will take a little shifting.

Munich was the signal for the digging of a defence system round the works, and for rush A.R.P. measures, including the camouflaging of the Works.

An additional sub-station assured a power supply should the main sub-station become a casualty. By 3rd September, 1939, when the voice of the Prime Minister, Mr. Neville Chamberlain, broadcast news of the declaration of war, the Marconi Company was already on a war footing.

Not only that: it was already on war production. For it was early in 1938 that the first Service orders were received. They were Admiralty contracts for transmitters and receivers of all types, for both big ships and small craft. They were manufactured by the Company from Service drawings.

THE NATURE OF THE WORK

Said the General Manager, who has grown up with the Company, leaning back in the red-leather chair, once Marconi's:

"Our plant is not a factory though things are made in it. It's a model shop. Most work in most factories means repetition. It involves the manufacture of standardized types and models adapted to conveyor-belt production—the belt moves and each worker merely performs a single, simple operation at a set speed, day by day, month after month."

"It's not so with the production of modern wireless and radar apparatus, where the work ranges from the making of large S.W.B.8 transmitters, with chassis of brass weighing from ten to twelve hundredweight, to small components wrought to a thousandth of an inch of accuracy by micrometer measurement.

"Such work can be done only by skilled and experienced craftsmen, and the man is more important than the machine; and neither can move until the scientist and technician have finished their jobs. For it is their work, after all, that is the soul of the organism."

THE LIVING ORGANISM

Let us look at this organism for a moment, for it is indeed, living, growing, changing, and tending always to move from the simple to the complex, as do all organic structures that have yet to attain their optimum development.

The organism is divided naturally into two major divisions. First, the technical side, secondly, the side which implements in the workshops the creative work of the laboratory and drawing office. This is the manufacture of the end-product. But whereas the laboratory criterion was based on scientific considerations, the manufactured apparatus must be such that it assures a survival value by the commercial criterion; it must be a sound economic proposition.

Research work, which is done in establishments at some distance from the main Chelmsford Works, is divided into two categories. There is pure research, much of which is mathemathical, since that science concerns electronics and all allied problems. This is, in the main, solo work, but always in close liaison with the élite of science research in British and foreign universities, government laboratories, and learned societies.

For example, one of the Company's scientific staff, a Fellow of the Royal Society, has lectured on his subject in many parts of the world. And throughout the War some of the most gifted and experienced of the Company's scientific staff went from the Company temporarily to undertake many kinds of research work for the Government.

The second category is concerned with *ad hoc* research, and is organized mostly in teams of scientists and engineers. These teams may have as end-object the confirmation or the development of ideas submitted by the pure research workers, or the improvement of existing apparatus. For example, ultra-high frequency transmission, echo-sounding, medium waves as used in broadcasting, or micro-waves as used in radar and other applications.

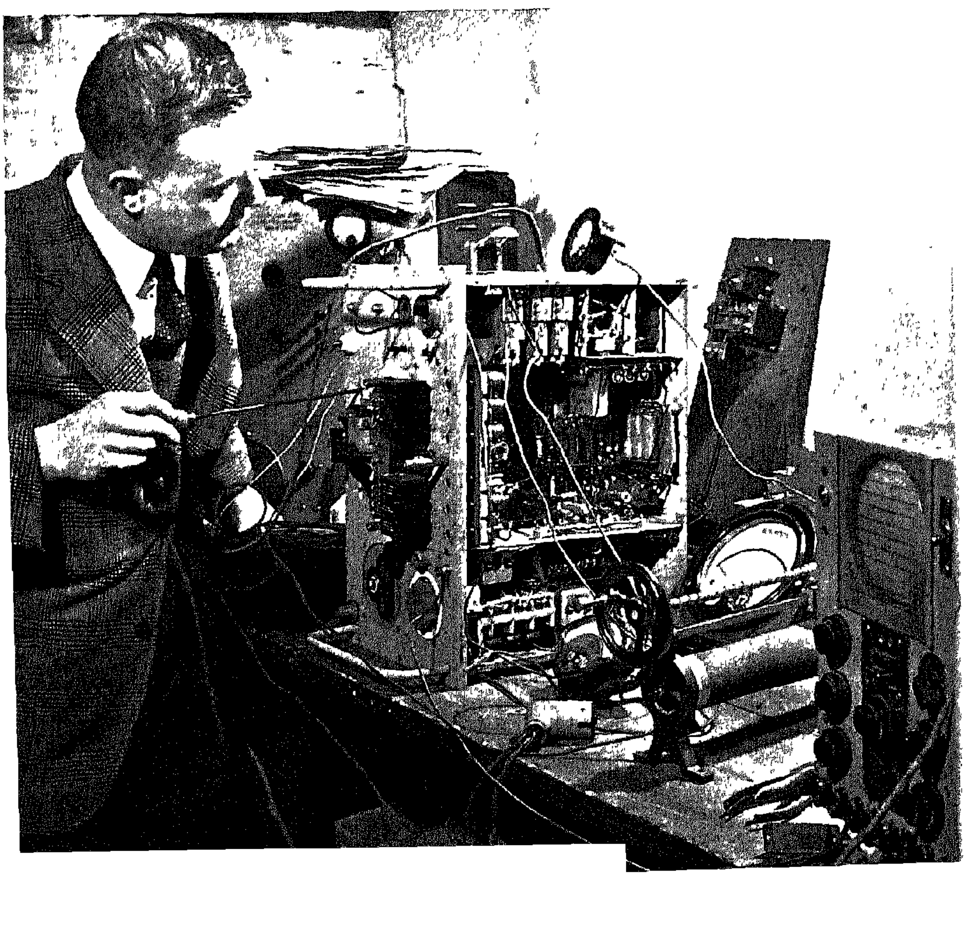
The range is wide, including medium and long-wave high-power transmitting, ultra-short-wave transmitting, high grade telephone reception, wireless direction-finding, measuring of equipment, wireless for aircraft, electro-medical apparatus, aerials, television, valves and cathode-ray tubes.

Each team of scientific workers endeavours to maintain constant liaison with other teams, and this two-way circulation of ideas and data might be termed, by analogy, the nervous system of this vital part of the living organism as a whole.

During the War expenditure on research, rightly regarded as the foundation of the Marconi Company's activities, passed the half-million sterling mark.

Last, there is the Development and Design Department which takes the product of both pure scientist and *ad hoc* scientific worker and gives concrete form to it. Thus, what began as an idea or theory, now stands on the bench, a completed model.

Development Engineer experimenting with first model



But a good idea, a sound theory, a completed model, though indispensable, are not in themselves enough. Now the commercial criterion must be applied. The decision now rests with the Designs and Development Department which, if the verdict be favourable, proceeds to develop the model and pull it together into a commercial design. Other criteria now come into the picture: size, weight, components, appearance. ease of manufacture.

These settled, the journey continues to the Drawing Office, where Works drawings are broken up into detailed drawings for the bench.

Next, all necessary materials of outside manufacture are ordered by the Supplies Department, and these all meet in the Finished Parts Stores. Everything is now set for the processes of manufacture in the Assembly Shops, after which the finished product passes to the Testing Department before packing and despatch.

WAR CONDITIONS

Normally, or ideally, these various activities and processes should function as a smooth flow from brain to hand; from the thinking mathematician and engineer, to the skilled bench operative. But in wireless and electronic applications generally, nothing is static at any time, and during the War it happened many times that half way along that flow a halt was called.

Somebody has hit on a better idea, a superior *modus operandi* and sometimes it is the enemy. This may involve a complete change over, and the scrapping of thousands of hours of labour, and thousands of pounds worth of material.

"When that happened during the War," the General Manager commented, "men who had been working full stretch in the consciousness that they were making a vital personal contribution to the War, were suddenly overwhelmed by a sense of futility.

"Working like that at high pressure, under black-out conditions, and often for weeks on end under air bombardment, realization that their work had to be scrapped overwhelmed them. It overwhelmed them: but it did not break their hearts—a supreme test of character."

During that period of intensive production, ease and speed of manufacture became paramount considerations, and thus the ideal design was seen as that into which could be incorporated the maximum number of standard components.

For example, the TR 1154/1155 transmitting-receiving set with which every British bomber and every Coastal Command machine that flew in the war was equipped, was a standard unit into the manufacture of which went many standard components.

In October, 1939, this receiver was merely "something on the back of an envelope". The first model was flight-tested by January, 1940, and complete equipment was installed in aircraft by teams of the Company's engineers by June of that year.

This outstanding job was done at that section of the Development Department which is housed at Writtle, birthplace of broadcasting in 1922, at that time under the supervision of Mr. P. P. Eckersley, chief engineer of the B.B.C. and (now Sir) Noel Ashridge of the B.B.C.

There is a background to this story of the bomber sets. Early on, Farnborough was designing aircraft, but the Focke was seen to be so superior that the development work was transferred to the industry. The R.A.F. carried on with equipment production only thereafter. Then, in 1939, with the great expansion of Bomber Command, the Air Ministry, dissatisfied with its own work, once more turned to the industry. The Marconi Company had equipped the Empire Flying Boats, and now the Air Ministry, having evidence of quality, decided to entrust this equipment to it.

NAVAL NEEDS

In 1939, the Manager of the Development Department was called to Portsmouth by the Admiralty. As the Company had been producing naval equipment in large quantities for a long time, there was nothing strange about this call.

The Manager and his Chief Assistant were received in a bleak hut in which two senior naval officers awaited them.

"What we want to know," the Scientific Naval Officer enquired, "is whether you can adapt your equipment to our special naval requirements?"

He was told: "Yes."

"And how long will it take?"

"It's an eighteen months programme."

"Well, we must have it in a month—ONE MONTH."

This was one of the first of those jobs that came at intervals throughout the War, taxing heart, brain and muscle with the merciless demand for speed and yet more speed.

The first model was produced in six weeks and three days. And that was exactly a fortnight after the outbreak of war.

The equipment called for had been designed originally for strictly limited production, and the problem set the Company's engineers was that of adapting it to quantity production.

This was achieved by centralization of design of the three classes of receiver, of which the CR 100 (as B.28) became standard in the Royal Navy, and was also adopted to a considerable extent by the other Services.

By this method of standardization a phenomenal stepping-up of production was achieved. Whereas in 1938, marine-class receivers were being produced sometimes by the few hundred, sometimes by the dozen only, the total war-period output of all receivers, including high-speed diversity units as used by Cable and Wireless and the Post Office topped the ten thousand mark.

That contribution was effective from the outbreak of war, and, in particular, for naval war purposes.

The rule of change, adaptation, and expansion, applied under the febrile conditions of war with ever-increasing pressure, sometimes produced curious and unforeseen consequences. Thus, more than once, production of a superseded unit continued side by side with its successor under pressure of urgent Service requirements. The battle could not wait upon the best and so, pending its production, was fed with what could be produced from current designs.

SKILLED LABOUR

In such work as that done in the Shops of the Marconi Company, work reflecting everywhere a scientific origin and character, the role of the unskilled, or semi-skilled, worker is, necessarily, limited.

It is probably true to say that in no other application of science to industry is so high a percentage of essential skilled craftsmen and women employed. Yet, from the earliest days of the War, the Company suffered the handicap of a constant drain upon its scientific staff and skilled labour resources.

This may fairly be described as a magnanimous contribution, and it was made willingly enough, though at a cost.

First engineers and technicians and several sorts of specialist, vanished to become temporary "Back-room Boys" in Government laboratories or, as temporary officers in the Services, while Service reservists, many of them very highly-skilled workmen, were recalled to the Colours in large numbers.

Thus the War exerted a double pressure upon the organism, increasing, on the one hand, the range and character of its work in research, development and manufacture while drawing away a considerable proportion of its man-power on the other.

Dilution was thus rendered inevitable. It was introduced with considerable misgivings, particularly as to the value of the girl recruits. The pessimistic foresaw friction between the sexes, working side by side at the bench, and some questioned the capacity of women for precision work.

Both fears proved to be ill-founded in the event. In every department girls and women did, and are still doing, good and often extraordinarily good work.

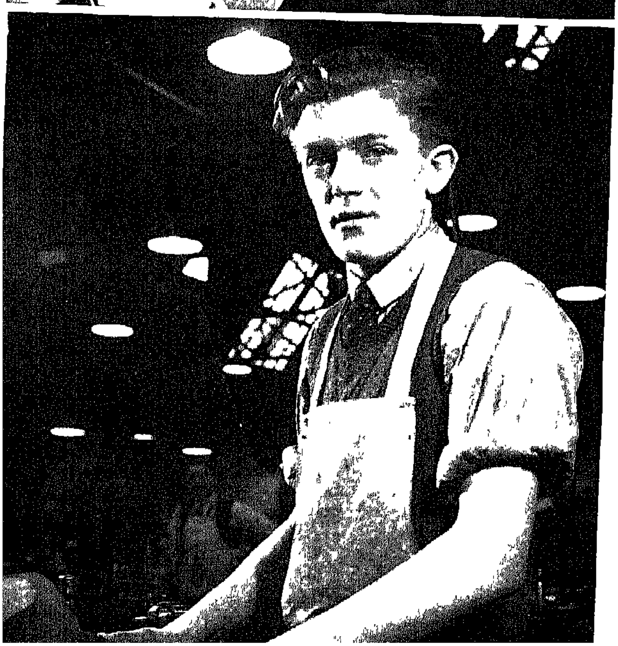
They have proved themselves steady and conscientious, and opinion is now unanimous that the best types of girl for work calling for attention to detail—and sustained attention at that—combined with delicacy of touch, are those who had already in civilian life acquired some degree of skill of hand and eye.

IN THE SHOPS

Let us look in at the Shops where five hundred girls are making simple things by simple processes, and complex things by processes that suggest the word "*mystery*" as it was used of his craft by the mediaeval craftsman.

Here are turning wheels, rotating lathes, whining drills and percussing hammers, making up the counterpoint against which pours forth a warm flood

Workshops Superintendent and Senior Instrument Shop Foreman, examining Magnetron Casting



Instrument Maker apprentice improver

Presently he became a time-served apprentice and picked up his first man's pay-packet. He rose, one step at a time, but with the precision of one of these machines that have been his life's work.

And now he is boss, with a "command" equivalent to two infantry battalions, or the ship's company of a light cruiser.

"You don't make an engineer or a craftsman in a month," he remarks, examining a small brass ring from the work-bench of a spectacled tester. "It's a matter of years, and, at that, there's always something new to be picked up because nothing stays put in wireless, and the research and designs people are always passing us something new to chew on."

WORKING AND LEARNING

This man became a craftsman, and he remains with his machines. He has reached the ceiling possible for his boyhood. But to-day, a boy entering these Shops has a choice of career and, if he so desires, can leave work-bench for laboratory and class-room.

In a way, this gateway to a career was opened up by conditions created during the First World War. That fact has both interest and importance.

In 1919, there was a dearth of qualified engineering apprentices, owing to the four-years lapse of articles between 1914 and 1918. In 1930, the Company decided to institute a scheme under which selected apprentices should be given facilities to study at technical college for one full day a week on pay.

This far-sighted policy made due provision against the contingency of another war. Consequently, the Company suffered no dearth of passing-out apprentices between 1939 and 1945, when the services of these young men were so vitally important to the industry.

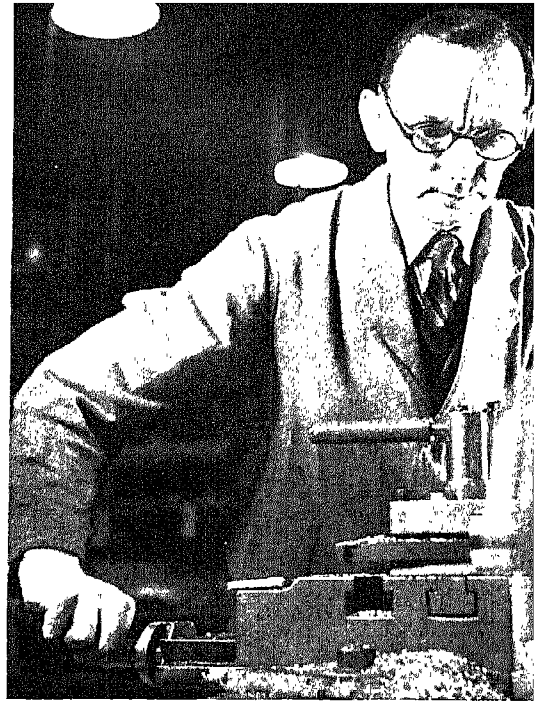
Throughout the War, this system was maintained, despite all difficulties, so that there is to-day no post-war hiatus in the recruitment to the industry of qualified engineers.

"When I was a lad," remarked the Shops' Supervisor, "an elementary school lad could not get to technical college or university. To-day, any of our lads can go right through to the degree of B.Sc., Engineering, and some of them do so."

In June, 1939, the Company employed 1,200 operatives; by June, 1940 it employed 1,900. The increase was steady and spread. By August, 1944, 6,000 work people were employed.

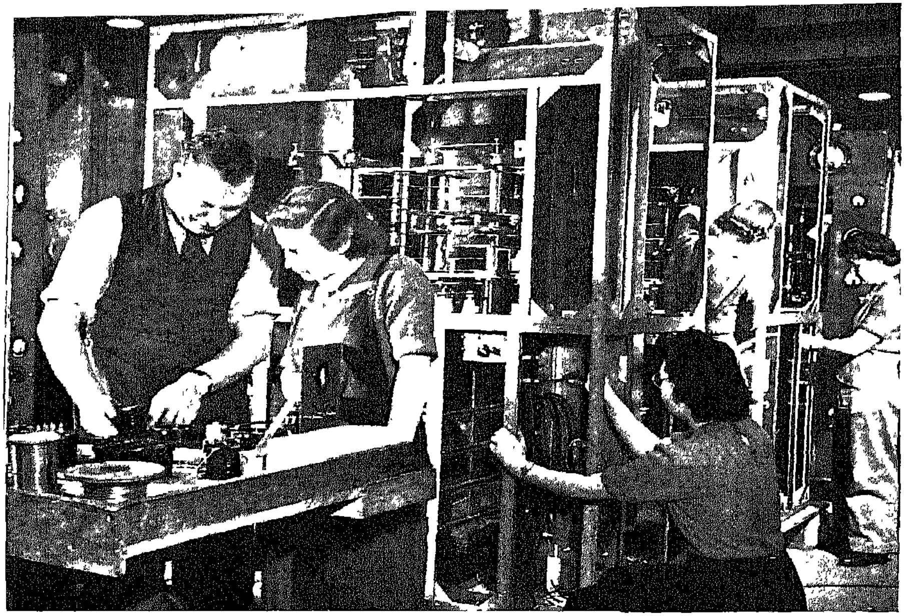
In 1938, the Company worked a five-day week. Throughout the War a seven-day week was worked. During that period, the Works were never shut, save partially and temporarily, as the result of enemy action.

View of section of Milling Machine Department



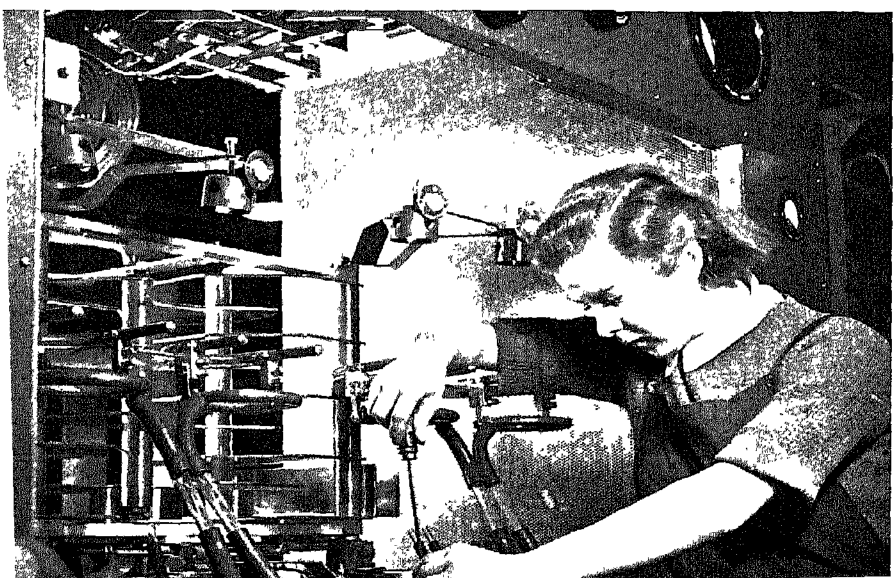
Operator turning a Casting

Girl Operator winding a Power Transformer in Transformer Section

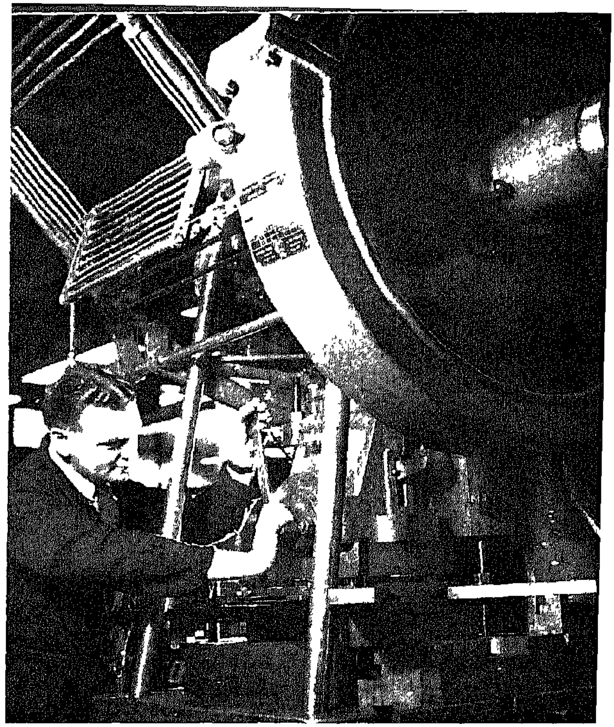


Chargehand supervising and instructing girl on work on s/w Transmitter

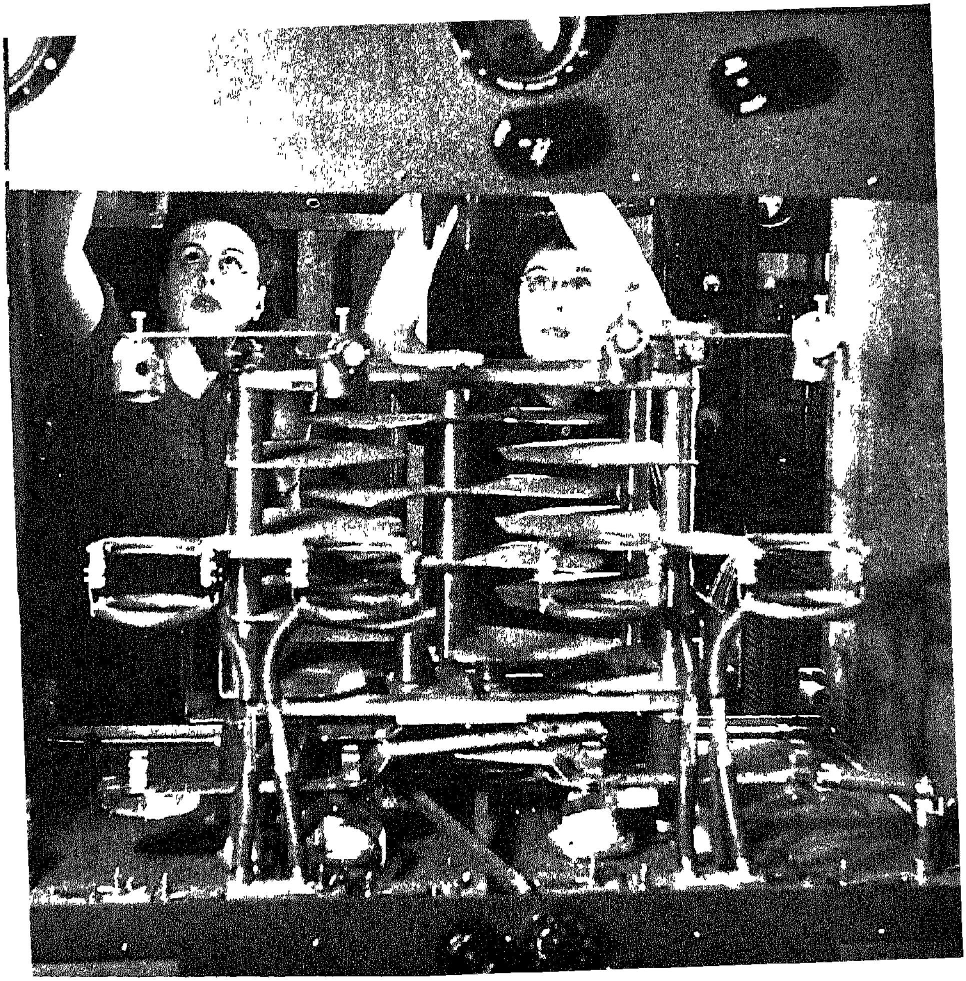
Girl adjusting Condenser on s/w Transmitter



Power Press at work in Tool Room



Girl Operator engaged on winding for small Transformer



Girls on assembly work on s/w Transmitter

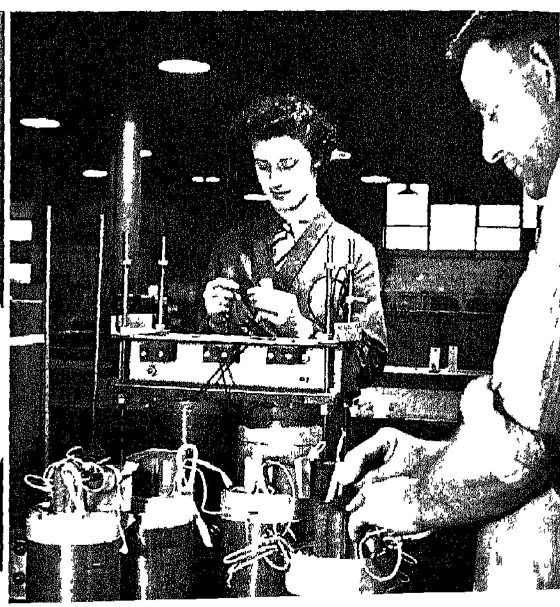
Men and Women Operators engaged on assembly of parts of Instruments in Assembly Department

Assembly work in the Instrument Shop

Instrument Maker assembling parts in Instrument Shop

Experience, knowledge skill . . .

Assembling Transformers



A Roof-spotter on Marconi House, Chelmsford

Girl Operator mounting a small component

II

THE BATTLE OF BRITAIN

"THE BLANKET OF THE DARK"

Mass daylight air attacks on Britain began on 8th August, 1940.

By the end of October of that year the gallant crews of our R.A.F. fighters, Hawker Hurricanes and Spitfires, had driven the Heinkels, Dorniers and Jus of the Luftwaffe out of the English sky. There ensued a lull, when the sirens fell silent, and it seemed to many that perhaps the ordeal of air bombardment was over and done with for good.

The respite, however, was of very short duration, for on 7th September, night bombing began, when, for a time, our barrage seemed to burst in vain against the night sky.

But the tide of battle, as we know, eventually turned and another epic had been added to the annals of the decisive battles of the world. And the air crews who survived were rightly hailed by a wondering world as the peers of the defenders of Thermopylae.

It is now permissible to tell at least a little of the role of radio and radar in that Battle.

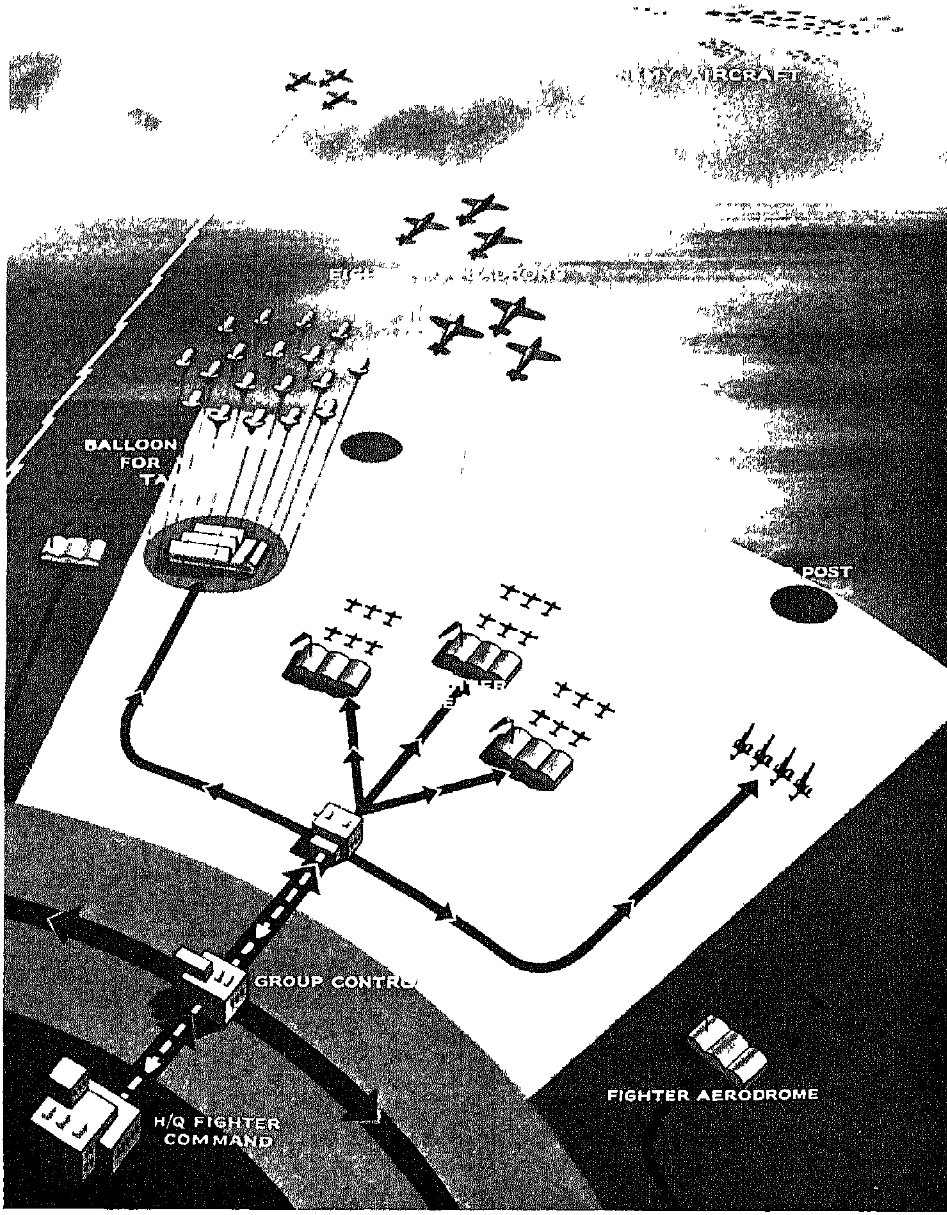
The scientific factors influenced the course of events during those crucial days. First, the increasing numerical strength of our bombers and the high standard of their equipment; secondly, the ingenuity of the counter-measures devised in government and industrial laboratories and developed in workshops at Chelmsford, and elsewhere.

BOMBER EQUIPMENT

Early in 1939, when Bomber Command was undergoing a great expansion, the Air Ministry, dissatisfied with its own work, turned to the industry. The Marconi Company, the pioneer in this field, with experience, plant, knowledge and skilled personnel, was approached and asked to produce two thousand sets for Bomber Command.

Up to that time, March, 1939, the Company had been limited for big-scale production, and this call for 2,000 receiver-and-direction-finder sets, though in itself no insuperable job, was beyond the Company's resources to do within the time limit imposed upon it by the Air Ministry.

Such situations became very common during the War in a number of industries. And it is of interest, as reflecting the hundred-per-cent. solidarity of the country in those difficult days, that when this situation had to be faced there never was any sort of industrial rivalry, but only a fellowship in which a number of companies worked in accord against time to complete much-needed war material, *as a single team.*



Intricate and flexible. This is how operations control was effectively organised

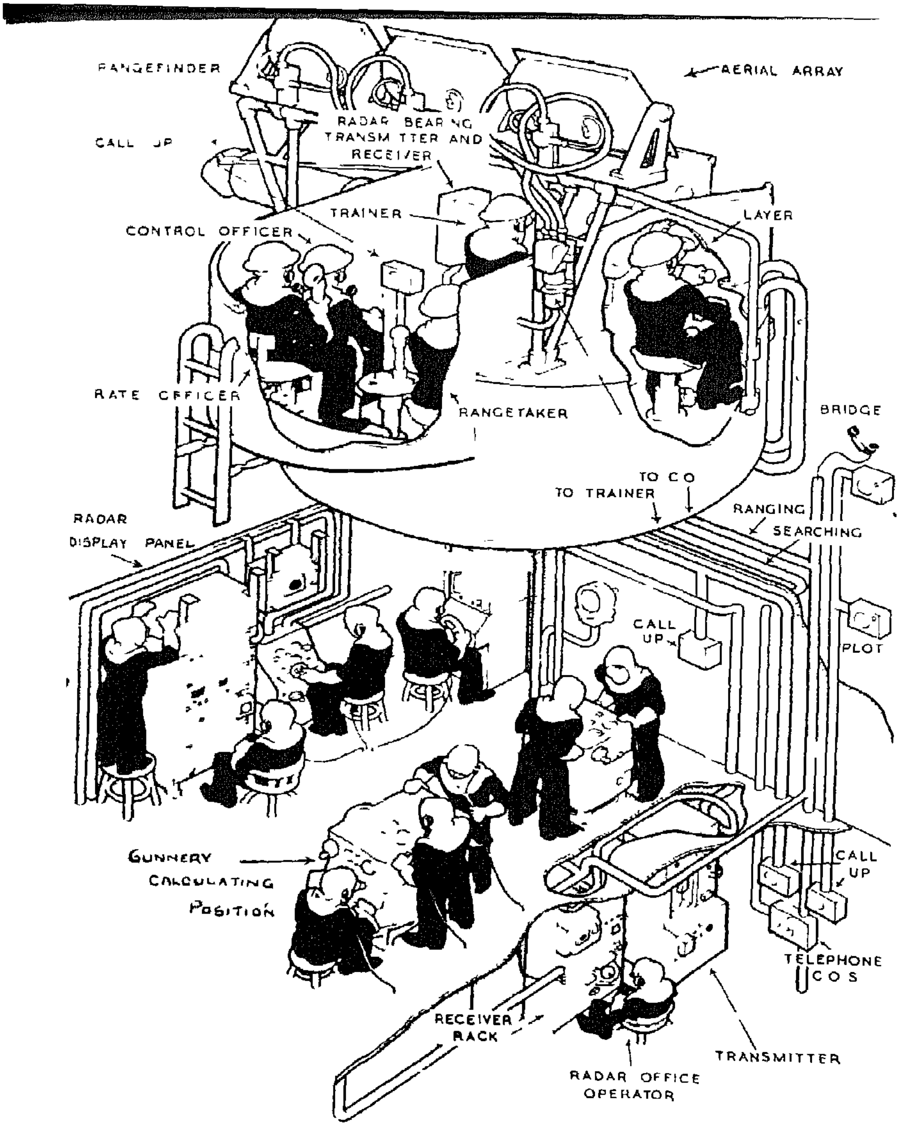
One of the A.A. guns whose shells were wireless guided to the fast flying target

In these cases it was usual for one company to be regarded as the "Parent" company, its associates as "Daughters". Thus, to secure delivery to time of the 2,000 receiver sets called for by the Air Ministry, the Company worked alongside other firms assigning to them, when necessary, members of its technical and scientific staffs.

Of this kind of single-mindedness of purpose which, undoubtedly, contributed to the total national war effort, Sir Stafford Cripps said:

"We could not, if we would, separate the contribution made by the government and industrial establishments . . . we treated all as partners in a single fellowship of science." And, again:

"In the development of a device which kept occupied a quarter of a million men and women, no one company could claim a total credit."



Signals are picked up by the aerial array. The Radar Operator (bottom) sees the "echo" and transmits its range to the gunnery calculating position. The Layer and Trainer in the gun director transmit to the gunnery calculating position the bearing of the target. If the target cannot be seen, the Radar display panel (left) is used to provide a Radar bearing and the guns are thus able to fire "blind". The remainder of the crew are members of the gunnery team

To which may be truthfully added: "Nor did a single company so desire.

It was, in fact, the Government's policy throughout the War to put researc and development into the laboratories which had the best brains and equip- ment, and that irrespective of identity of employer.

Work upon the first of these Bomber Command sets was begun 22nd Octobe 1939. It was completed 2nd January, 1940. From the "back of an envelope stage, to flying and production in quantity, was achieved in five months.

The receiver equipment made by the Company for Bomber Comman constitutes one of the largest contracts for a single piece of equipment in th whole War, and represents a sum well over the million sterling mark.

For the general public, the problem of speeding up aircraft production, a that period of the War a burning issue, was one of speeding up the manu- facture of aircraft. But it was not quite so simple as that. Often, there entere into the picture a scientific factor, a factor apparent only to the technician, problem upon the solution of which all production depended.

DASHBOARD GADGETS

To the uninitiated, the instrument board of a modern fighter or bombe aeroplane is a maze of clock-faces and dials in bewildering variety. Yet eac has a use, and none is a frill.

In the early days of the First World War, pilots flying machines that b modern standards were little better than death-traps, found that in fog o cloud they were unable to fly on an even keel, and generally emerged into th clear air either at a dangerous bank, or on their backs.

By 1932 R.A.F. machines were fitted with pitch-indicators, and bank-and- turn indicators. Wireless direction finding, also, came in about that time, process of flying on bearings given by wireless signals from the ground, thoug it was never a success.

Now, a standard Beam System is used which leads the machine in to it base. The pilot simply switches on and selects the frequency on which his home station's beam works.

Through his headphones he hears the signals which tell him whether he i left or right of his true course for home. Left is indicated by dots, right by dashes, true course by a continuous note.

This equipment, together with the ground wireless beacons, inner and outer markers, each sending out a distinctive signal, make the way in plain eliminating many "by-guess-or-by-God" methods.

These gadgets are indispensable to the pilot.

When an aeroplane is equipped with wireless apparatus—which is virtually always—certain problems are thereby created.

One of these is that of preventing a spark discharge caused by static charges This difficulty is now overcome by the careful bonding of the craft, that is to say, by carefully joining up all metal parts with small pieces of copper wire.

This procedure provides continuity, all bad electrical joints between members being short-circuited by the binding wire. At the same time, this measure maintains all the members of the air-frame at a constant potential, thus preventing a spark discharge due to static charge.

Again, wireless apparatus in aircraft has to be completely screened from the mass of high-frequency currents, magnetoes, leads and sparkling-plugs of its engines. Of this sort of equipment the Company manufactured some 72,150 sets in all.

Throughout the War, no bomber flew that did not carry Marconi equipment of one kind or another, and few Spitfires flew that were not equipped with the Company's Stabilivolts. When full production was achieved, the output of Stabilivolts was 8,000 a month.

THE MAGIC BEAM

In the very early days of the War, before Italy had come in against us, an R.A.F. officer travelling in mufti in Italy, became interested in the talk of two Fascists in his train compartment.

One, who had a strong German accent, was boasting a good deal about the prowess of the Luftwaffe, and of the devastation then being wreaked upon England by its crews.

The Italian, beginning to show signs of resentment, remarked: "That's all very well, but why, then, do you send aeroplanes to bomb rabbits in the Shetland Isles?"

"Ach, that," replied the other, "we do those flights because it is the longest land-fall we can get. You see, my friend, if we strike the coast at the point we are aiming at we know that this new radio method of ours is working well."

The R.A.F. officer was not on the technical side and so did not understand the precise meaning of what he had heard. But he was shrewd enough to record that encounter and to pass on the information to Intelligence when he got home.

With that and other items gathered here and there, our Intelligence secured a complete picture of the trend of German experiments in the beaming of skytracks.

It was on such beams that the fighters and bombers of the Luftwaffe flew on their way to bomb Britain. And it was by playing pranks with those beams that a senior engineer on loan from the Marconi Company to the Air Ministry, along with other technicians, was the means of fooling the enemy and of saving many civilian lives.

Even to-day, there are to be found in isolated country fields and bye-ways, in remote woodlands and other parts of the countryside, old bomb craters, by now acquiring a decent covering of green vegetation.

Why, the passer-by wonders, were bombs dropped with so little regard to targets?

The explanation may now be given.

Attacking aircraft flew in on a beam, one of two radiated from two widely separated points on the French or Belgian coasts—one, perhaps, from Brest, the other from Calais.

These two beams intersected over the target. The incoming bomber merely continued on his way, with a little weaving, no doubt, and similar evading action, until he came to that sky point where the two beams intersected. And there he dropped his bombs.

A number of transmitters, supplied by the Marconi Company, were used to put a cone of wireless energy under the track of the attacking bombers. This cone bemused the pilot, deflected him from his true beam course and enticed him like an electronic Lorelei to follow after, until, thoroughly mystified and perhaps becoming a little nervous, he unloaded his bombs haphazard and made for home.

The magic beam had lost something of its magic, thanks to a repeated conversation, plus a clever idea. And these same fertile brains thought-up another headache for the enemy.

On this occasion the result was accomplished by the Puckish device of putting the enemy's signals back at him, to his utter bewilderment and that of his air crews.

Yet, like most brilliant ideas, this one was very simple. The enemy's signals were recorded on a small tape machine which gave perfect reproduction of them: and then they were sent back to him.

ENTER RADAR

As far back as 1934, the Cabinet of that day requested the industry's researchers to concentrate on air defence. By 1937 some ground radar stations were already in being. By the end of 1939, a chainof stations reached from Scotland to the Isle of Wight, to the considerable mystification of the general public.

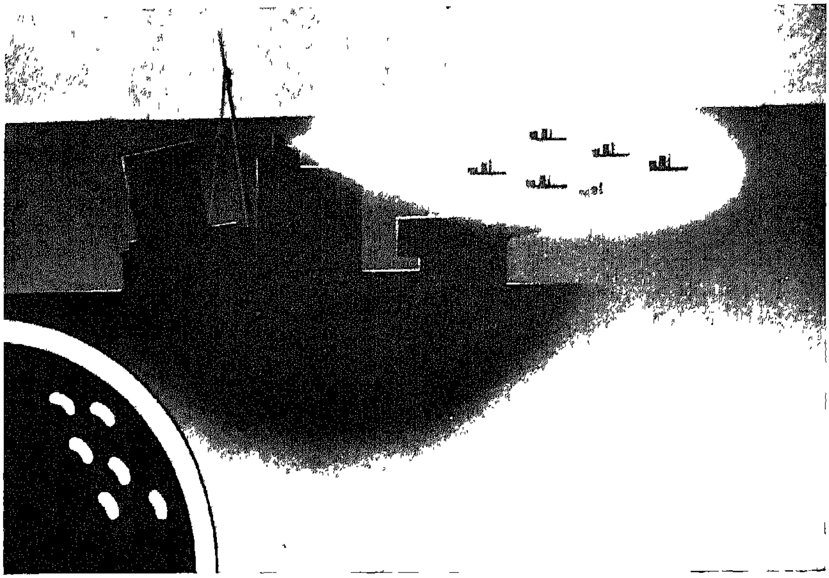
But before relating the part played by the Company in the drama of radar we must go back a little.

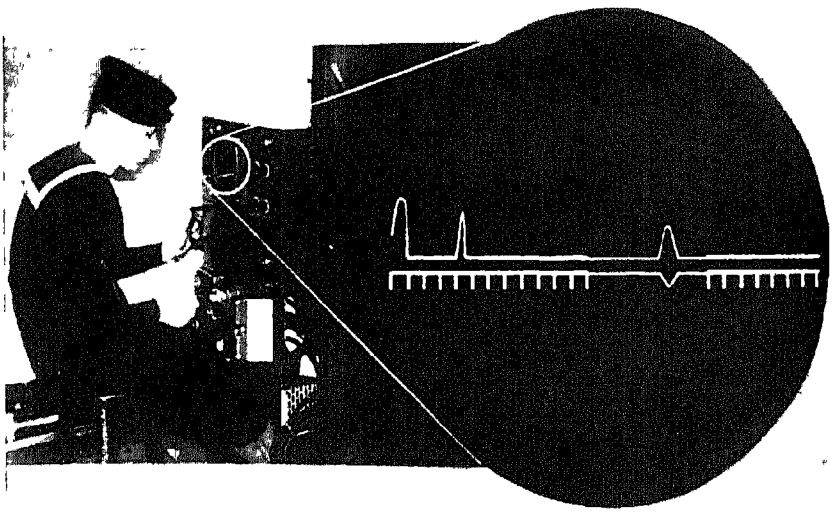
On 30th May, 1916, the Observing and Interception and Direction-finding Stations of the Royal Navy received signals on their wireless direction-finder—the pioneer scientific work on which was done by Captain Round, R.N., of the Marconi Company—which told them that the German Fleet in Wilhelmshaven was doing a mighty lot of signalling.

That was in the morning; and the observer reported the circumstance.

In the afternoon, he sent in another report: this time to the effect that a German battleship was steaming out of that port on a northerly bearing.

The German fleet was putting to sea, and the direction-finder, precursor of radar, had made the Admiralty cognisant of it. At once the First Sea Lord, Sir Henry Jackson, ordered the Fleet to sea. And thus the Battle of Jutland was joined.





Above, By Radar the surface ship has picked up enemy ships. These are shown as bright marks on the dark screen in the left hand corner.

Below, What a gunnery Radar Operator sees. The target is shown by the inverted "V" on the right of the upper trace. He has matched the lower "V" and the range is thus transmitted automatically to the guns.

Direction-finding in those days was done by virtue of the transmitting station at the other end. Radar combines transmitter station and receiver in one—as a man throws a ball at a wall with the right hand and catches it on the rebound with his left.

A simple image may serve to make the distinction clear to the non-technical reader.

THE POND IMAGE

When a stone is dropped into a still pond it produces radiating circular waves that travel at an even speed in widening circles towards the pond's periphery.

Any obstacle in the path of these waves, a duck, for example, at once produces radiation of another series of circular waves, and these, or some segment of them, are returned, or reflected, back to the point of origin of the first radiation, namely, that point where the cast stone fell.

In radar, instead of water waves, there is a radiating discharge through the ether of electrical energy pulses on 10 meter wavelengths, or less, of a millionth of a second duration, and moving at the known speed of 186,000 miles per second.

This radiation "floodlights" a wide ether area, betraying all aircraft in that zone, and thus making possible the determination of distance and direction of the object reflected back with mathematical exactitude.

By the time the first fury of the Battle of Britain broke the Air Ministry had decided to ring the whole coast with radiolocation sites; for the R.A.F. were adhering to the old maxim of war, namely, that the best form of defence is attack.

DIONYSIAN EARS

Dionysius, of Syracuse, fearing his enemies, caused to be constructed a great artificial ear whereby he was enabled to hear the talk of those within his palace.

Radiolocation—now radar—by plotting the courses and indicating the numerical strength of the approaching attackers, provided Britain with a modern version of the Dionysian Ear, and made possible the logical disposition of her fighting squadrons.

This was of supreme importance, because of the disparity between the respective strength of the R.A.F. and the Luftwaffe. Thus, as soon as the German pilots took off, our fighter squadrons were manoeuvred into position.

All mechanical work on the forging of this invisible series of "ears", or girdle of "vision", about the British Isles was carried out by the Marconi Company which was given orders to erect twenty-six radiolocation sets. The time factor being all important, part of the work was spread to other companies, but all the aerials were made and erected by the Company's engineers.

The Company was given this work, so vital at that time, because it alone possessed the special knowledge, personnel and materials to handle it.

Very early on, the Germans decided that by flying in low their bombers could slip under our radar beams and get in unspotted. This stratagem was countered by the radar "chain home" low stations. Strung out along the coast, these stations watched for all low-flying aircraft.

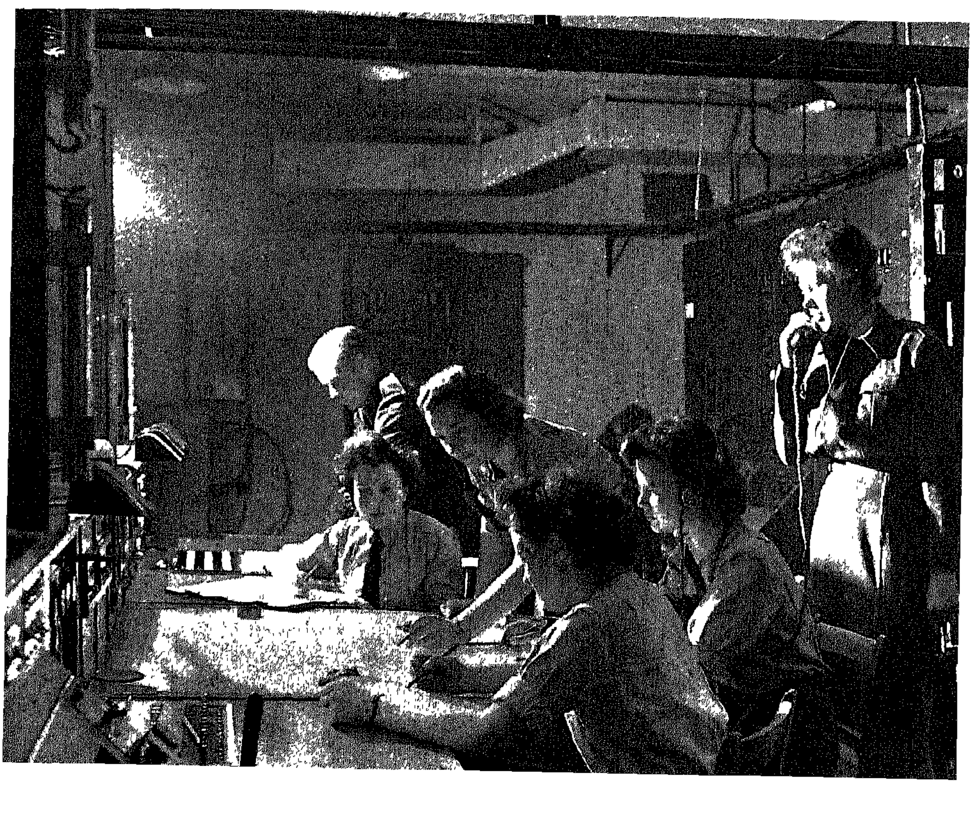
Their aerial equipment was a power-turned, five bay, four-stacked array (the CHL) mounted either on a twenty foot gantry or a 185 ft. tower, according to the site in relation to sea level.

An enemy machine, duly reported by the radar reporting chain, was "passed" to radar ground controlled interception stations, and G.C.I. directed out fighters until within close range of the enemy.

By 1942, the fixed type of station was able to deal with numerous raids simultaneously and was directing all fighters in its operational sector.

At that time the Company was acting as consultants to De Havillands, for which firm it evolved the special aerial and direction-finding loop that became standard fighter equipment.

Airwomen plotting aircraft on the Cathode-Ray tube



Their instruction aircraft carried Marconi apparatus—receiving, transmitting and direction-finding gear, complete.

Alongside work on radar and direction-finding equipment for the Air Ministry, on ground control interception, on air interception gear, as carried by reconnaissance machines, on searchlight control, the siting of A.A. guns and searchlights, the Company kept pace with every demand made on its plant and personnel for ordinary Service radio equipment: and nearly always against time.

AN INVISIBLE BATTLE

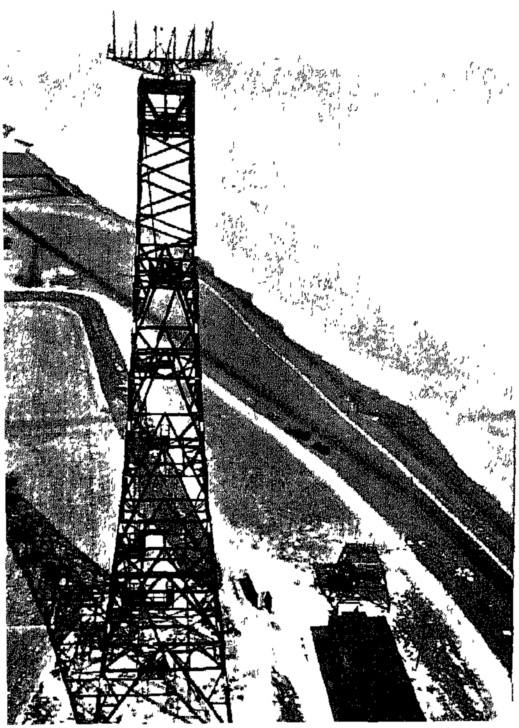
To the people of Dover, Ramsgate and Deal, the thunder of gunfire became the normal daily experience of many abnormal days. And at night, boom and flash far out at sea brought next day's rumours of shipping sunk.

It was no secret, even in 1940, that the too-efficient night shelling in the Straits of Dover was radar-directed fire.

Could it be stopped, or mitigated, and, if so, how?

In November, 1940, the Marconi Company was asked by the Admiralty to second an engineer to examine the situation, and as a temporary officer R.N.V.R. a senior man was set to work.

Technically considered, the job presented no insuperable technical difficul-



An aerial view of a "Chain Home" Low Station

ties. It called for a careful sieving of all sounds in the ether not identifiable as radio signals. And the fun began at once.

What the enemy was doing was crystal clear. He was sweeping the Straits, back and forth, with a radar beam, or beams, and laying his guns whenever the tell-tale echoes gave him the position of his invisible moving target. It was like shooting sitting birds, and, it may be added, all radar-controlled activities are as lacking in the element of chance.

DAVID AND GOLIATH

Now, it is a commonplace that ever since the beginning every weapon devised by man has produced a counter-measure.

The strategy of Goliath was based on brute strength; that of David on good markmanship, or combat at distance.

Had he survived that well-directed blow, Goliath, one may be reasonably sure, would have thought up body armour against so elusive an enemy. And David, on his side, would certainly have countered with the element of cunning and, like Bruce at Bannockburn, have plunged an unsuspecting, armoured enemy into a deep concealed pit.

So it was in that invisible battle that was waged across the grey waters of the Straits of Dover. It was a duel in which the element of cunning was the chief and most remarkable characteristic.

How were we to employ our own radar to stop this nightly destruction of our shipping? That was the question posed, and the obvious answer: *By jamming him*, did not happen to be the right one.

Our radar had enabled us from the outset to detect both enemy air raids from the moment of the take-off, and the presence of U-boats lurking anywhere within several hundred miles of our coastal waters.

That is to say, radar was, for us, predominantly, a *defensive weapon*. As such, it possessed supreme value.

HIDE AND SEEK

But in the Straits of Dover the enemy was using his radar *offensively*, fingering through the etheric dark to the invisible labouring merchantmen in the Straits, and thereafter destroying them with the deadly precision of his radar-directed gun fire.

Were we to use our radar offensively, also?

Should we set about locating the enemy's radar transmitters on the other side of the Straits and bomb them when found?

There were few technical difficulties, and certainly none beyond the efficient radio engineer.

Simply stated, it was a question of whether we could risk disclosure to the enemy of the quality and extent of our radar development, then of paramount importance for defence. And it was decided that we could not.

It was for that reason that there was no jamming of enemy radar transmitters operating against our shipping in the Straits as a fixed strategic policy. Instead, our radar was organised to establish the extent of the enemy's radar control, and thereafter to bewilder and bemuse him.

A CONVOY GOES THROUGH

The first listening post, a small van, began operating in November, 1940, from the high cliffs of the South Foreland. Two enemy radar transmitters were located, one operating from Boulogne, the other from Cap Gris Nez.

That night a large convoy was expected to pass through the Straits. Darkness fell. The German radar beam swept through, back and forth. But no convoy was reported by a returning radar echo.

Meanwhile, the listening North Foreland got the wave length, seventy-eight to eighty cm.

Then, all being set, the radar men went to tea. And at that moment the first shell fell. Soon a rain of shells from the radar-directed enemy coastal batteries were bursting among the ships of the convoy.

On this occasion the jamming rule, as counter-measure to gun-fire, was honoured in the breach.

To the North Foreland from Dover came the urgent question:

"What can you do?"

"We can jam them, sir."

"Start right in."

The jamming was plugged in at once and continued for two hours. But within a few moments the shelling ceased and the guns fell silent.

And the convoy limped through.

Thereafter, throughout the Battle of Britain, and after that, a warfare of cunning developed in the ether. Station after station was set up until there were a hundred and seventy listening ears strung out along the white cliffs of England.

There was jamming when there was nothing going through, and even when ships were in the Straits. And wavelengths were switched and changed, then changed again, in a sinister game of hide-and-seek. Receivers were taken aloft by barrage balloon to get optical range, while the enemy multiplied his radar sets and we improved our monitoring.

Little ships were sent into the Straits as decoys, to draw the enemy radar beam when specific information was needed. The enemy sought our listening radar posts. We replied by screening them electronically, thus making them radar-invisible.

A ship stubbed her blunt nose at a bare seven knots into the choppy sea, and the enemy radar sought her in the protective radar fog in which we enshrouded her, and sought her in vain. . . .

Shortly after the War, a German radar technician who had been on the French coast throughout was asked what he thought of our radar warfare.

"At the start," he replied, "we were certainly ahead. But you caught up and after that you were always one jump ahead of us."

That German might well have been surprised had he known that the men who organized that counter-radar campaign had solved their scientific problems in a huddle of huts on the cliffs within sound of the boom of the sea.

OUR SCIENTISTS JOIN UP

In April, 1940, the Government, through the Ministry of Supply, made its first call for Marconi personnel when ten members of the scientific staff engaged on ionosphere and propagation conditions began work as the "Eckersley Group".

In September the Instrument Section of the Company's laboratories began to co-operate with the "Eckersley Group" as the "Kemp Group", under the aegis of the Air Ministry. This Section grew very rapidly and ultimately was assigned technical control of part of the operational intelligence service.

For peace conditions the Services establishments had been adequate, but the scale of the War very soon made it clear that the whole technical and scientific resources of the country as represented by the Services establishments, universities and industrial laboratories, would have to be pooled for maximum efficiency.

In May, 1941, an arrangement was made with the Admiralty under which the remaining Great Baddow Laboratories staff, and that part of the large, well-equipped laboratories not already taken over, were to co-operate with the Admiralty Signal Establishment. Thirty Research and Development Engineers were then seconded by the Company to the Experimental Establishments of the Admiralty, Air Ministry and Minister of Supply.

This absorption of personnel had the effect of masking the Company's scientific contribution to the War, while the Great Baddow Laboratories themselves vanished, as it were, to become, variously, an Admiralty Signal Establishment Extension, an Air Ministry Research Station, or an R.A.F. Operational Station.

Some of the consequences of this transformation were amusing. Departments of the Services that were unaware of the changed position began to direct correspondence to "the Royal Naval Dockyard, Great Baddow", or to the Royal Naval Base, of the same address, though there is no water in that part of Essex. One letter was safely delivered which had been addressed to Radio Whipsnade, another to the Chaplain, R.A.F.

All such changes were part of the general pooling of the country's scientific resources; and the key-note of all work done was that of the team.

The Marconi Company had a finger in most of the research pies baked during the war years, but rarely was it responsible for the entire dish which nearly always included ingredients from Government Research Establishments, the universities and industrial research, with Allied co-operation from overseas.

About this time, a cruiser lay under an impenetrable fog in a northern port. Said her Commander to the Trinity House pilot: "Can you undock her?"

"Yes, sir, I can. But I can't take her safely to the sea through this," indicating the fog.

"Never mind about that," replied the Commander, "I can handle that end of the job."

That is a story which is a reminder of the high degree of secrecy which was built up and successfully maintained about radar development. Not long after, in 1941, radar was to function on a dramatic and historic occasion, namely, when Mr. Winston Churchill and President Roosevelt met on H.M.S. *Renown* in mid-Atlantic to agree that declaration of peace aims which became known as the Atlantic Charter.

A dense fog descended over the waters, blotting out sky and sea. Yet the great ship made for home at her full speed of 27 knots, for radar gave her navigating officers eyes and ears, and for them it was as though the air were crystal clear.

When the Battle of Britain could be written off as won, the Luftwaffe had lost 144 night bombers, and Hitler, having bruised himself against the West, was turning to the great attack on the Soviet Union, and thus exposing himself to that wound which was to prove fatal to Nazi Germany.

In that Battle, the part played by radio and radar may be described, without hyperbole, as paramount.

War stimulates those sciences which serve its purpose. Radar is an outstanding example of the truth of that statement. But radar, giving a fabulous vision to men at war, and making possible even the measurement of projectiles in flight, provides also eyes and ears to serve the purposes of peace. As yet we are only at the beginning.

III

THE BATTLE OF THE ATLANTIC

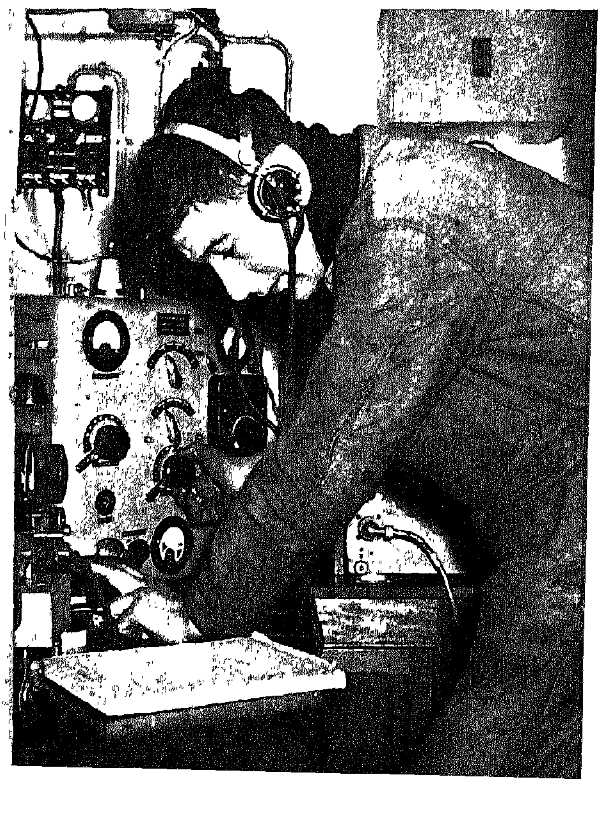
THE WESTERN OCEAN

Those who fight battles do not alone determine the final issue, nor even mould the character of the combat. For a modern battle begins to take shape in the brains of solitary men, and teams of men, in study and scientific laboratory; in factory, workshop and shipyard.

In a world of scientific discovery, invention and technology, every battle, in the final analysis, is a battle of brains. Courage alone is not enough, and perhaps it never was enough.

True, in the Battle of the Atlantic courage, "the lovely virtue", in Sir James Barrie's phrase, shone before the eyes of men as the star which guided Ulysses of old. Even so, the prolonged struggle for the mastery of the Western Ocean became, as it developed, more and more the contest between invisible forces remote from the watery wastes of the battlefield, though most potent upon it.

Radio-equipped were the M.T.B's which hunted the E-Boats that infested our coastal waters



For the British Empire, then fighting alone, defeat in this great sea battle involved total disaster. Over these grey heaving waters plodded the ships of the Merchant Navy bringing the blood of life, and the blood of battle, to these Isles: raw materials, manufactured arms and, above all, food.

And athwart that sea-path was cast the wide net of the marauding U-boat, the unpredictable peril of the Nazi commerce raider.

The contribution of the Marconi Company to this great battle was three-fold: men, machines, ideas.

As the battle developed, the quality of communications, counter-measures and scientific devices of all kinds, became vitally important. And it was upon these that the Company's scientists, engineers and technicians and work-people laboured full-stretch.

U-BOATS

There was no period of phoney war at sea.

In the first six months, three merchant ships were being sunk for every ship built in the United States and Great Britain. It was as bad as that.

These heavy casualties were being inflicted by such famous commerce raiders as the *Graf Von Spee*—sunk off the River Plate, 2nd October, 1939—and the celebrated *Bismarck*; by bombing and mine-laying aircraft and, most intensively of all, by packs of merchant-ship-hunting U-boats.

The conquest of the U-boat peril became at once a major war issue; and the Marconi Company has a certain pride in the contribution made by it to that end, in men, equipment and in fertile ideas.

Already the Company had been supplying the Royal Navy with a wide variety of wireless and, more recently, radar range-finding equipment, in particular with a certain type which was to assume so great an importance in U-boat counter-measures.

To the Merchant Navy, through its associated Company, the Marconi International Marine Communication Co., Ltd., had flowed a steady stream of wireless equipment and trained personnel for operation and maintenance.

U-boats, naturally, were most vulnerable when surfaced, which they were under the necessity of doing when it was essential to communicate by wireless, to charge batteries, or to take in supplies of fresh air. And this they were able to do with comparative immunity from detection or attack under cover of darkness.

AID TO SURFACE VESSELS

From the outbreak of War, aircraft had been equipped with Marconi Aid to Surface Vessels apparatus which indicated the presence of shipping. But it was not until 1942, when sinkings had risen alarmingly to an average

daily loss of sixteen thousand tons, that a new version of A.S.V. was introduced.

By means of this new device, surfaced U-boats could be detected at night—for radar knows neither light nor dark—and were thus robbed of their former night-time immunity from attack when surfaced.

Then ensued one of those strange duals between opposed scientific and technical teams which so often joined issue in the War. The first dramatic event was the capture by the Germans of a complete A.S.V. set.

Clever technicians, they were soon familiar with its principles and hard at work producing its antidote, or counter-measure.

Soon after that mischance, U-boats nosing out from St. Nazaire, carried the remedy against our A.S.V. equipment. It took the form of a receiver covering the wave lengths of the A.S.V. radar.

The idea was clever enough, for such a receiver would be sensitive to the A.S.V. beam directed upon the surfaced craft. More than that, this counter-measure gave the U-boat time to detect the approach of a Coastal Command bomber and to submerge with an ample safety-margin of time. Those aircraft, Sunderlands and Liberators, had become one of the U-boat commander's headaches early on. They scoured thousands of miles of sea on U-boat patrol and, day and night, wirelessed their finds to base, thus raising the hue and cry.

THE MICRO-WAVE SET

At that point in the Battle, then, the original A.S.V. had to be considered as cancelled out by the ingenuity of the enemy, and, consequently, something new had to be produced. And the trend apparent was the development of apparatus designed for the radiation of shorter and ever-shorter wave-lengths.

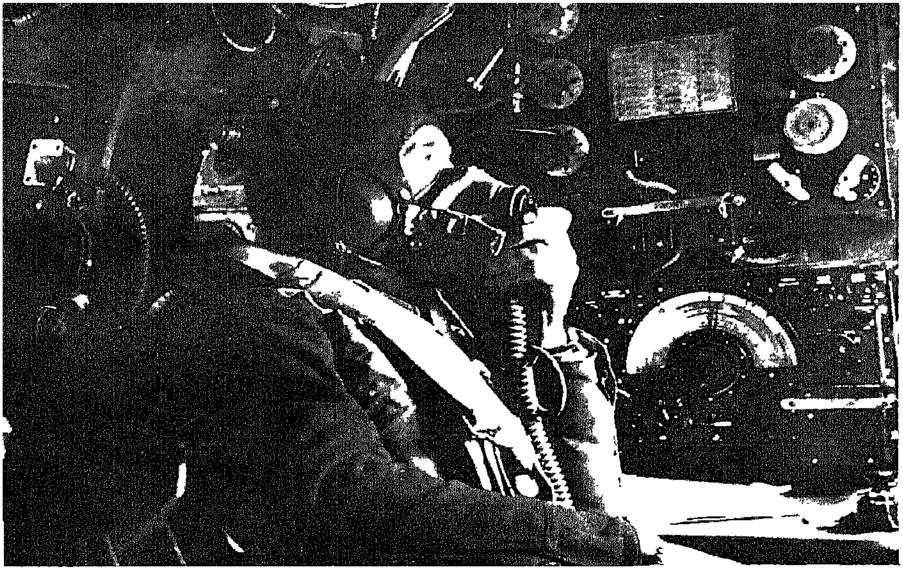
By 1943 the first A.S.V. micro-wave sets were in service, an effective answer to the enemy at once reflected in the sharp rise in the figures that followed their use in U-boat sinkings.

Though they tried very hard, the German technicians were unable to solve this one, and thereafter produced *schnorkel,* the system of bringing the fresh air down to the U-boat, instead of the U-boat up to the fresh air.

The work of the Marconi Company in this ding-dong scientific warfare was at that juncture mainly focussed on production, and a very wide range of radar equipment for the Royal Navy and Merchant Marine was manufactured at Chelmsford and elsewhere.

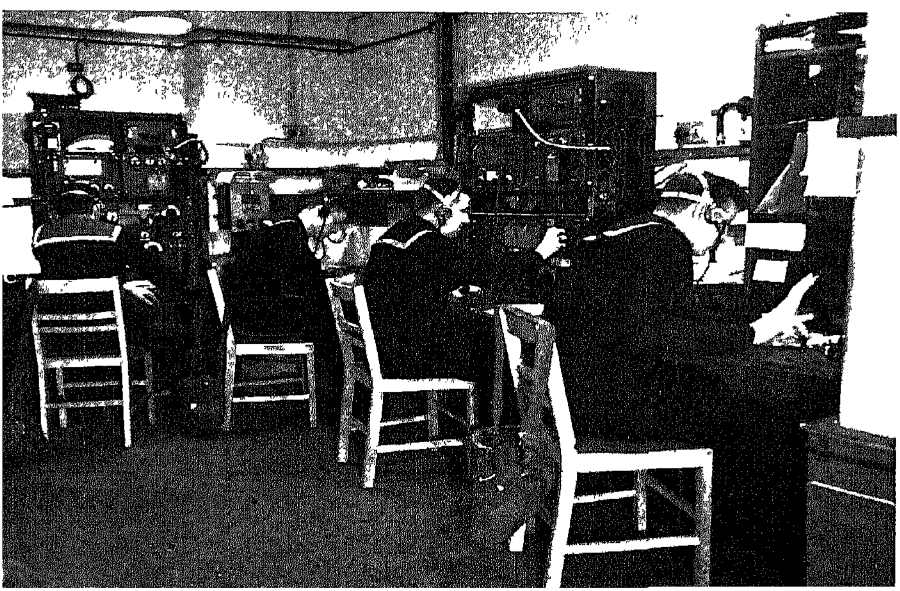
This output was stepped-up from very modest beginnings to figures that would have been regarded as beyond plant and labour capacity under normal production conditions.

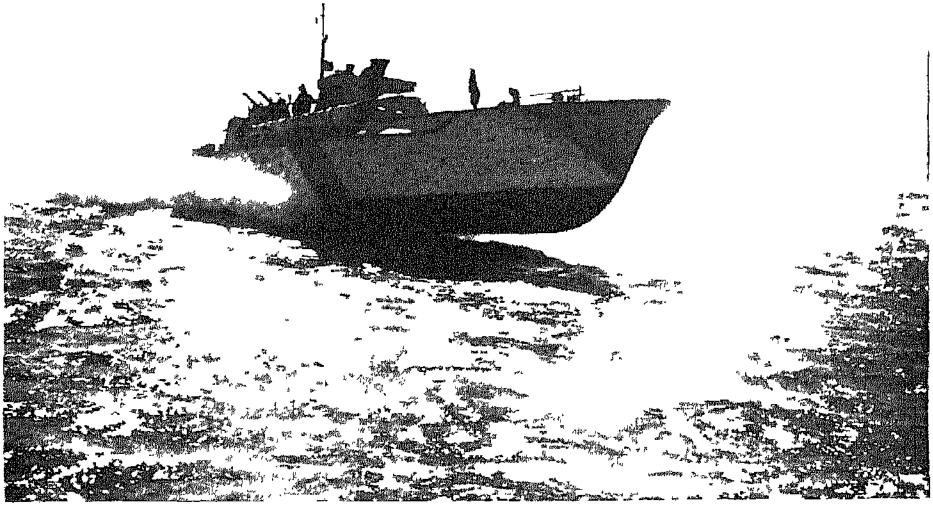
Besides this manufacturing output of radar equipment, the Company carried out developments and designs based on ideas originating in the Telecommunications Research Establishment.



The eye from the air saw the U-Boat, the Wireless gave the word

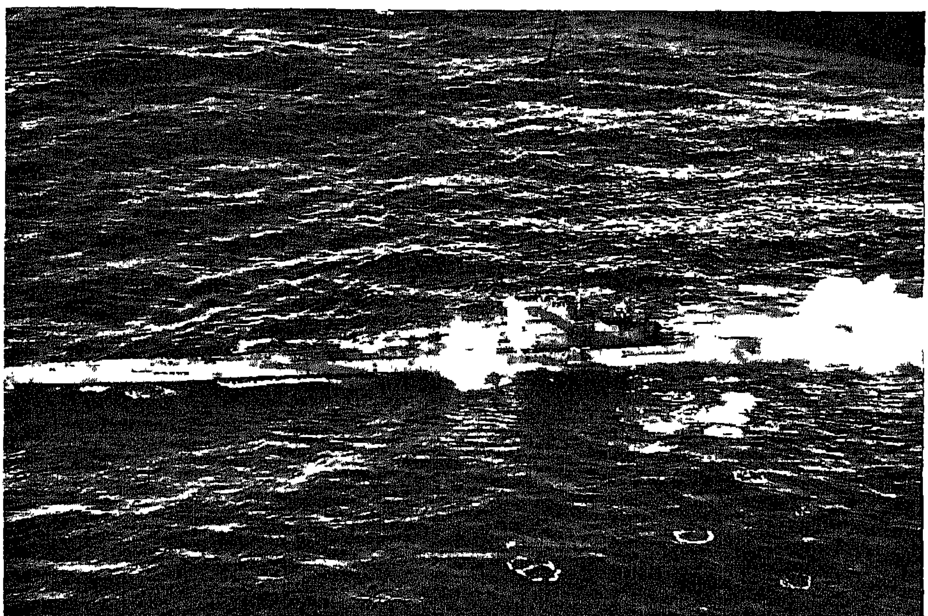
Into this room by wireless comes news of the Western Ocean





A wireless-equipped "Guerilla" of the Royal Navy a M T B at speed

Located by wireless, the U-Boat is attacked and sunk by Sunderlands in the Bay of Biscay



SCRAMBLED SIGNALS

A located U-boat could be made the quarry in a sea hunt by fast naval craft armed with depth-charges. This circumstance made U-boat commanders chary of using their wireless apparatus. But signals had to be sent at times, and to circumvent the betrayal of message or position, an ingenious device was used.

Signals were sent out in which the words were divided between wavelengths, and were thus "scrambled" until they presented what appeared at first sight to be an impossible riddle in the art of decoding.

A member of the engineering staff of the Company, at the time on loan to the Air Ministry, produced the effective counter-measure to this clever dodge. He had set up a row of Marconi receivers and got between them the whole scrambled message, a sort of verbal jig-saw. This was then quite easily put together, producing the message in clear.

NAVAL RADAR

Perhaps the greatest contribution the Company was able to make to the final destruction of the U-boat packs was a Naval radar set, which was fitted in all corvettes and destroyers.

The Company was asked to produce a set along these lines on 14th March, 1941, and the job proved to be just another of the many designated "crash" which fell to its lot during the War.

By putting all available labour on to the job, and by working round the clock, the Company was able to deliver the first model by 15th April. Then, within a few months of the first call made for them by the Admiralty, 250 sets were handed over.

Thus set down, such a feat of production may not sound particularly impressive. Yet it involved the mobilization of a complex scientific and industrial organism, plus, to its limits, the endurance and stamina of many men and women.

Speaking at a Radio Industry Council luncheon shortly after the war, Sir Stafford Cripps said that if examples were needed, the final defeat of the U-boats sprang to mind. A hundred A.S.V. sets in aircraft and a couple of hundred sets in destroyers and corvettes, assured the defeat.

These sets went as a request to the contractor on 14th March, 1941, as a set of incomplete sketches on 24th April, and emerged as a successful model on 4th June, to be followed by two hundred and fifty sets within the following seven months.

"Anyone who knows or who has seen that set can judge how remarkable was that production performance. The sunken submarines mark its success."

WE ARE BLITZED

By May, 1941, all war work connected with shipping had become exceedingly urgent. Sinkings had risen to alarming levels, and it was quite well known

that no shipbuilding programme could hope to offset such losses as those suffered in the previous month, namely, 488,124 tons.

The whole outlook for the Battle of the Atlantic was then exceedingly grim, for although Roosevelt had adopted his escort plan, it was but a half measure, while the President of Harvard's call for "naval belligerency" was a gesture only, though a heartening one.

Early on the morning of 9th May, 1941, a single enemy plane came in low over Chelmsford and dropped two bombs, turned, and dropped two more.

Three fell on the Marconi Works direct.

One exploded in the centre of the Machine Shop. The second detonated on the floor of the transmitter erection shop. A fire was started by this second bomb which consumed the paintshop. It was got under by the Company's own fire brigade.

Seventeen people were killed, and forty injured.

The following day, when all hands were hard at it cleaning up the mess, a worker reported tapping sounds from under the debris in the wrecked transmitter erection shop. Frantic efforts were made to work through to the source of the signals with crow-bars and shovels. Finally, the conclusion was reached that nobody was buried there, or, if buried, still alive, and rescue work was suspended.

Next day this great pile of debris was finally cleared away. Underneath, still ticking, was uncovered the third bomb.

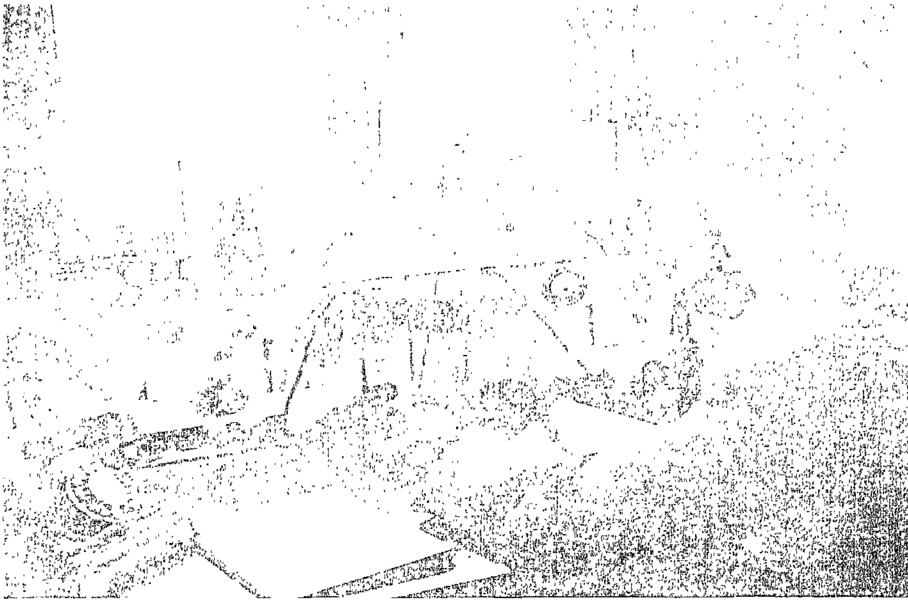
This bomb had to be blown up where it lay. This was necessary, but a disaster. The detonation blotted out the paint-shop, and the sand and blast section was badly damaged so that for a long time thereafter those two processes had to be done in the open air.

Production was not entirely shut down and was soon picked up to 80 per cent. of normal in temporary quarters and in a large carpenter's shop lent by Crompton Parkinson Ltd., for a period while new buildings were hurriedly put up. One sub-station, supplying power, had been wrecked. A temporary sub-station was erected at high speed from spare parts within a few hours—but, alas, so near the still-undetected unexploded bomb that the detonation of it wrecked the make-shift sub-station entirely.

In the early days of the War, when enemy bombers were passing overhead all the time—for Chelmsford was in Bomb Alley—everybody used to go to the shelters when the alert sounded and stay there until the "All Clear". After roof-spotting was adopted, shelter was taken only on roof warnings.

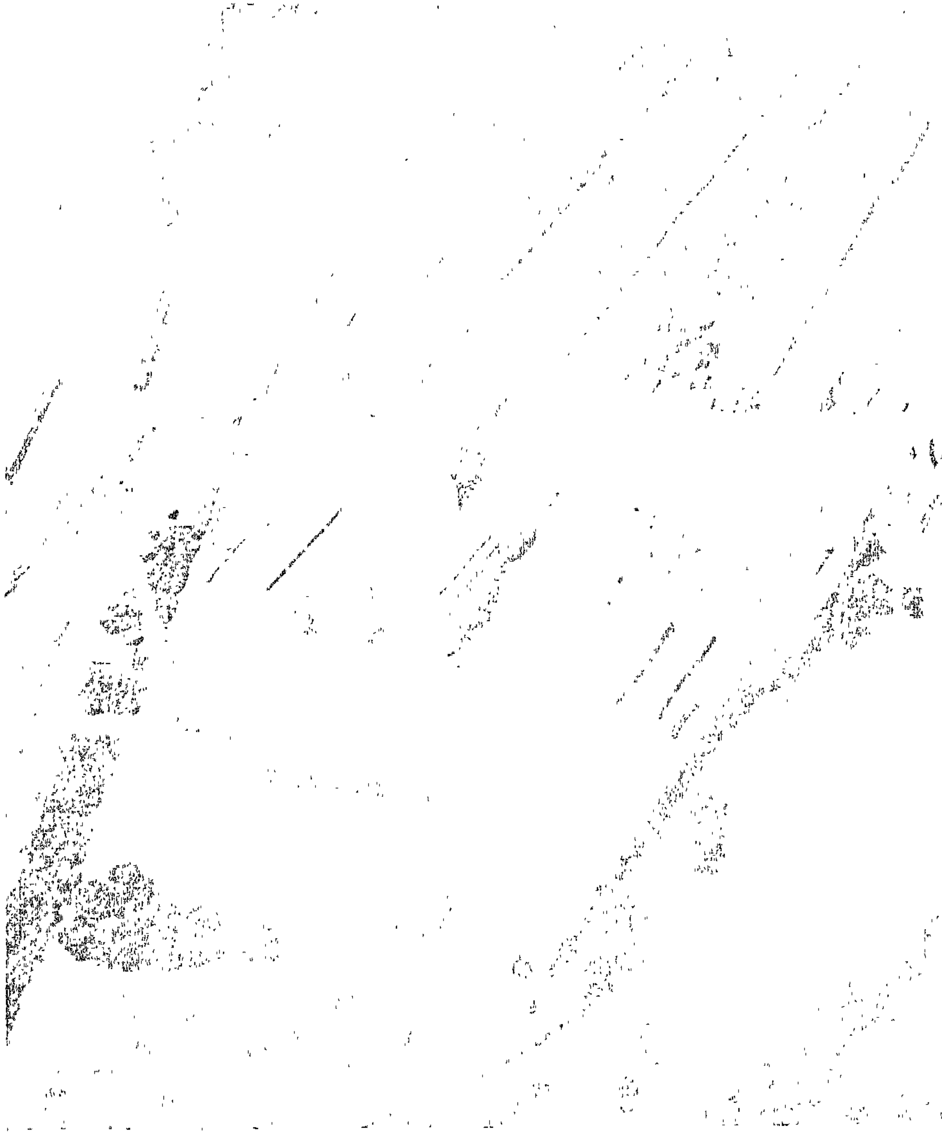
At the outbreak of war the main work of manufacture was carried out at Chelmsford. In the Autumn of 1939 a large factory was taken at Vauxhall for sheet metal and frame construction work, and for components for aerial engine ignition screens. Premises were taken also on the Albert Embankment in the late Spring of 1940, and at Hackbridge, for the manufacture of bomber sets.

The Vauxhall premises were hit by bomb, 27th September, 1940, the damage being partial only. Work was immediately transferred to other premises at



The wireless room of a Balloon Barge operating on a busy waterway

Day and night, Sunderlands and Liberators scoured the U-pack infested Western approaches



On the 12th June, 1945, officers of "C" Squadron, 8501 Wing, R.A.F., located in the fire-gutted photographic building on Quedlingburg Airfield, Germany, a scale model of the Marconi works, Chelmsford, as prepared from aerial photographs. The model was presented to the Company by these officers of the R.A.F. and now stands in the main entrance of Marconi House.

Parson's Green, Fulham. Then, on 10th October, the Vauxhall premises received a direct hit on their yard which brought to an end all work there. Casualties included one killed and two seriously injured.

As a result, all sheet metal work had to be transferred to Hackbridge as a temporary measure. It was a period when many of the Company's people were rendered homeless and became part of the great shelter community of the bombarded city.

Next misfortune of war came in the form of a rain of incendiaries on the Fulham premises, 20th February, 1944. Even so, work did not stop, the activities of the gutted Fulham premises being switched at once to a Romford factory which had been taken in August, 1943.

At Broomfield, the small factory for the manufacture of CR 100 Receivers was blown up by a land mine, 14 May, 1943. Miraculously, nobody was hurt, and all turned to salve gear and material from the debris.

Grevious as were these catastrophies the morale of the Company's people—spoken of by the Chairman, Admiral Grant, as his "ship's company"—remained, as it did, indeed, until the final "All Clear", above all praise for steadfastness under perpetual conditions of danger and cool courage in the hour of disaster.

THE END OF THE BISMARCK

On 31st May, 1941, an aircraft sighted the *Bismarck* and *Prinz Eugen* in a Norwegian fjord hideout. This was the View Hallo that started one of the greatest sea hunts in history and ended with a kill, in the Bay of Biscay.

It was a hunt of prime importance since every German surface ship roaming the seas constituted a perpetual menace to both convoys and ships steaming solo, and the powerful *Bismarck* was among such craft the most formidable.

This famous sea chase has another interest, also, for the Marconi Company, since it illustrates in a classic manner how a perfected system of wireless telegraphy, throwing out its nervous impulses from a central ganglion—the Admiralty, London—renders the manipulation of a great Navy at sea a scientifically precise operation.

This chase, then, one that is comparable to Nelson's pursuit of the French fleet under Villeneuve to the West Indies—prelude to Trafalgar—demonstrated the revolution in sea warfare brought about by the development of wireless signals. And it is there that the cardinal change is found, rather than in that from sail to steam, though a chase of 1,750 miles in four days is impressive enough in itself.

From that pursuit all naval craft, aircraft and their land liaison, the shore-based Coastal Command, were unified for communications by wireless apparatus supplied by the Marconi Company. And thus there was built up a pool of information which presented a complete picture of a battle situation spread out over many thousands of miles of the watery surface of the earth.

"FIND, FIX AND STRIKE"

A naval engagement that demonstrated the supreme value of the modern direction-finder and radar took place in the half light of an Arctic winter day on 26th December, 1943.

The presence of the *Scharnhorst* in those waters, where she was lurking to attack the Murmansk convoy, was first ascertained by direction-finding stations strung out along the spine of England.

The Home Fleet, commanded by Admiral Sir Bruce Fraser, H.M.S. *Duke of York*, thereafter became one single attacking organism, an instrument of destruction whose parts consisting of destroyers, cruisers and battleship were made one by a unified electric nervous system.

The distant direction-finders had located the *Scharnhorst*; next each ship's radar found and fixed her. Bad visibility, darkness, availed the German not at all. From dawn she was pursued from that point S.E. of Bear Island where she was radar-"seen" steaming at twenty-eight knots in the direction of the Murmansk convoy. While destroyers and cruisers closed in on her, the Flagship, H.M.S. *Duke of York*, came up, made contact and delivered the *coup de grace*. At 4.15, as darkness fell, the *Scharnhorst* registered the first hit. Night fell, but the eye of radar pierced the dark, and the great raider perished in flames that cast their glare over the Arctic Sea.

The sinking of the *Scharnhorst* was a classic example of a sea-action completely and perfectly orchestrated by wireless signals and radar data.

The revolution in sea warfare that has followed on these scientific developments, which started with Marconi's first primitive experiments close on half a century ago, is brought out by a comparison of the signals employed in three historic actions of which the sinking of the *Scharnhorst* is the third.

At Trafalgar the last signal hoisted by Nelson was flown before the first shot was fired. Thereafter each captain, having his orders and knowledge of Nelson's plan of battle, fought his ship without further amending or modifying orders, for smoke and fire in any event made flag signalling impossible.

At Jutland we see direction-finding and wireless in their early stages. H.M.S. *Lion* was, in fact, the first ship to be equipped with direction-finding apparatus. In that action there were 650 ships on both sides, scattered over a large area. In the British Flagship plotting was by means of direction-finder which yielded a general bearing, and that only at such times as the found ship was "electrically alive".

Thus information was imperfect throughout the action and synchronization impossible. Admiral Jellicoe was dependent throughout on signals, and these depended on dead reckoning. In short, there was an inevitable margin of error due to the limitations of the wireless apparatus of that day.

In the *Scharnhorst* action we see the effect produced when a complete battle picture is shared by all ships engaged, making it a precise scientific operation to "find, fix and strike" the enemy.

THE SWAT UNIT

The dislocation of a ship's wireless apparatus was an obvious end-object for the German Naval Staff, since a ship thus gagged was unable to put out her call for help through the listening ether.

The merchant ship sailing out of convoy along the lonely ocean path and pounced upon by an enemy raider, surface warship or submarine, was a too-frequent calamity in the early days of the Battle of the Atlantic.

When this misfortune overtook a ship the first enemy orders to her master were more or less standard. He was ordered to stop his ship and cease transmitting wireless signals. And the penalty for failure to comply was standard too, namely, torpedo and gun-fire. Naturally, any master who considered his ship in danger of being sunk tried to send out messages calling for the assistance of a British warship in the hope that his crew might be rescued.

Aware of this, the enemy frequently used decoy calls with the object of dispersing the British Fleet and thus enabling them to sink single merchantmen in greater safety.

This procedure, perfectly fair in war, was producing anxiety in London, and the Company was invited to think around the problem. This its scientific and technical people duly did, and they produced, as effective counter-measure, a device that automatically swung the frequency right through the transmitting wave band and back at a steady rate. Since this device was only fitted in British merchantmen it rendered the operations of the decoy ships futile.

This device, which became well-known as the Swat Unit, was put into production at once and attached, as an automatic electric mechanism, to the standard Marconi transmitters already installed.

The Swat Unit made it impossible for German surface raiders to rely on decoy ships for the dispersal of the British Navy.

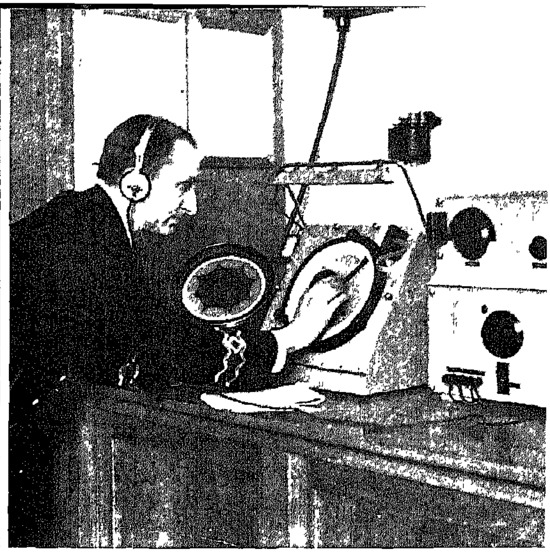
All Admiralty stations were, of course, advised at once to be on the *qui vive* for the new Swat signal, and the method proved of great value, saving many ships that, otherwise, would have been sunk without trace.

THE MARINE COMPANY

When war broke out all shipping came at once under the Admiralty. One of the first requests to the Marconi Company had as object the immediate creation of a world organization to assure a hundred per cent. efficiency in the wireless apparatus carried by British shipping.

The Company was asked to establish at once depots abroad to service radio equipment for naval craft and all shipping under Admiralty charter. It was also asked to undertake to service and generally look after vessels flying the White Ensign equipped with Marconi apparatus. This included a very large number of ships of the small auxiliary type.

Such activities were, of course, well in line with the Marine Company's



This Officer has thirty-one years of service. On the *M.S Port Lincoln* he has both Radar and wireless

Wireless room *S.S. Strathallan* showing Radio Goniometer

S.S. Dunster Grange, whose master said, "Three times his vigilance saved the ship."

The functional importance of radio is reflected by the modern equipment (*S.S. Port Lincoln*.)

ordinary course of business, which is to equip ships with wireless apparatus, telephones and echometers, doing so generally as the renter.

But thovgh there were few and only minor technical problems in what was required of the Company by the Admiralty, there was a very real *quantitative* problm. For this step-up called for would have been fairly represented upon a graphby a near-vertical line.

Take, for example, the matter of trained personnel. It is one thing to increase unskilled labour, or even semi-skilled labour; but it is not possible to turn out a trained and efficient Radio Officer in days or even weeks. The job takes many months.

THE RADIO OFFICER

In the ordinary course of its business the Marine Company supplies trained Radio Officers to operate the equipment supplied by it under contract. But these men are not trained by the Company, for Marconi College, at Chelmsford, is concerned solely with post-graduate instruction on the scientific side, and the Marine Company has never set up a school inside its organization.

By law, every Radio Officer aboard a British ship, must hold the Certificate of the Postmaster-General in Wireless Telegraphy. Such graduates enter the Marine Company's service when qualified and are assigned to ships as required.

When it is borne in mind that a ship such as the *Mauretania* normally carries eight Radio Officers, and that directly war was declared all ships were required to operate over a twenty-four-hour watch, involving a double complement of Radio Officers, the nature of the task that confronted the Marine Company in those early days may be imagined.

Before the War it had in its service two thousand Radio Officers. During the first year of hostilities it enrolled no less than six thousand—a three-fold increase.

In the last War, operators needed under similar conditions of urgency were trained in the Marconi Schools, a makeshift arrangement that served its purpose but indicated the need for something better.

To meet this contingency, therefore, the Government advised all private schools of telegraphy to speed-up work by lengthening their working days, and by increasing their staffs. Meanwhile, the normal year's course, leading to a First Grade P.O. "Ticket", was supplemented by a wartime six months' Special Certificate.

The Marine Company has a number of depots at the principle home ports, and sub-depots at smaller points, to service ships. These, on their peace-time establishment were quite inadequate for the tremendous demands of war.

WIRELESS FOR ALL

Ships that formerly went to sea without wireless were now required to carry it. This called for the rapid equipping by the Marine Company of trawlers

and drifters, and their conversion to Admiralty war-time wireless requirements as mine-sweepers. At the other end of the scale, the Company had to instal equipment in large passenger liners which were then being converted into armed merchant cruisers.

Working with a limited staff, the Marine Company tackled this work from its East Ham Head Depot and from its local depots, installing Marconi equipment in a range of craft that included destroyers, corvettes, sloops, fighter-direction vessels, submarines, trawlers and drifters.

All this work was carried out in close association with the Admiralty, whose Port Wireless Telegraph Officer was accommodated on the Company's premises, and who was to write, long after their demolition by enemy action: "The Marconi International Marine Communications Co., Ltd., has been of the greatest assistance to this Department throughout the war period."

It was when the Battle of the Atlantic might be said to have passed its crucial phase that this servicing Depot received the direct hit which cost the lives of two of its staff, and wrecked the premises.

The peak period of activity coincided with the worst phases of the Battle of Britain, when seven of the depots were hit, and Southampton Depot was blotted out, and Hull and Grimsby very badly damaged.

A BLITZ IMPROVISATION

The destruction of the Southampton Depot in November, 1940, was an episode in one of the worst raids upon that city of the whole war. Only a burnt-out shell and rubble remained of the Depot when daylight came.

"The problem that faced us," said the Depot Manager, "was to carry on with the uninterrupted progress of the ship work. We had lost all records, all stores, nearly all transport facilities, while all telephones were down throughout the whole Southampton area.

"We had already adopted the policy of dispersing stores throughout the docks to minimise just such a contingency as faced us on that bleak morning. So we set off through the ruined city by car for the docks and compiled a list of all undamaged equipment.

"Then, later that day, we had a hurried meeting and organised and redistribution of equipment among the ships most in need of it. Next day urgent supplies arrived from Chelmsford. We found an empty house and were re-established after two days."

That is a laconic account between the lines of which the reader must read the untold story of courage, resource and pertinacity.

THE EMPIRE HAIL.

Stories of heroism at sea by Marconi Radio Officers became familiar newspaper reading throughout the War. They enshrine some of the splendid acts of self-abnegation and devotion to duty recorded by our men during those

years. And they are reflected clearly in the list of decorations and awards made, though even more in the long casualty list of such officers.

Among the distinctions thus gained were the O.B.E. (2), D.S.C. (2), M.B.E. (15), Lloyd's Medal, and Commendations.

The story of the *Empire Hail* illustrated another aspect of the work of the Radio Officer at war, namely, the part played by quick wits and presence of mind in circumventing the enemy. And it is but one of many.

On 15th March, 1941, a Radio Officer of the *Empire Hail*, sailing in convoy from Greenock for Savannah, Georgia, got distress signals from an oil tanker.

A week earlier the convoy had received wireless orders to scatter following attacks by Focke Wolffes, each ship to proceed on its prearranged course.

The distress signalling oil tanker had been one of that company.

The distress signals received by the *Empire Hail* were being preceded by the signal RRRR, and this suggested strongly that the oil tanker was being either attacked or stalked by U-boat or surface raider.

Reception of these signals was also being badly jammed by two powerful transmitters whose operators appeared to be enjoying a pleasant little chat in Spanish, one using spark, the other I.C.W.

As the *Empire Hail* man put in when telling the story later:

"They doodled on their transmitting keys, but directly that oil tanker tried to get her message away they had plenty to say and talked the poor tanker down."

"On the direction-finder I got the spark transmitter's bearing and found that it was almost identical with the oil tanker's. I turned to the other fellow and found that he was north of us. And then I began to do a bit of hard thinking."

This Radio Officer retransmitted the distress signals of the oil tanker and his own and the unknown's bearings, together with all information about the two powerful jammers, to Portishead. In order to slip past the jammers, he did this on high frequency transmission which is less liable to jamming.

He then left his office and made his way to the bridge, where he found the Master. There the following exchange ensued:

M. "That tanker's being jammed by the enemy, all right. Well, I propose to run south and dodge him."

R.O.: "If you do that, sir, he'll get us with his direction-finder."

M.: "Well, what would you do?"

R.O.: "I'd run east, sir, for I look at it this way. If the enemy is at the centre of a circle, and we are on its circumference, then for each degree of error caused by bad navigation, steering and the like, the distance will be greater on the circumference the longer we can make the radius."

M.: "Yes, that makes sense."

The Master of the *Empire Hail* accepted this piece of reasoning, probably with memories of the Euclid of his school days, and presently night fell on the heaving waters.

Then that R.O. came once more to the Master.

R.O.: "I think, sir, we might be wise to run north now it's dark."

M.: "Why?"

R.O.: "Because, if that was the enemy jamming, then he will probably make for France after sinking that tanker."

M.: "I don't agree at all. I think he'll run north and make for Norway. Therefore, I propose to run south." In the event, both proved to be right.

For the two *Spaniards*, and a third—though possibly genuine—who joined in the chorus a little later that night, calling plaintively to Las Palmas, and hopelessly, too, on a 500 kcs. transmitter, were very soon identified.

Thanks to the sagacity of that Marconi Radio Officer, the *Empire Hail* made a happy landfall at Savannah, having safely slipped past the *Gneisenau* (spark), the *Sharnhorst* (I.C.W.) and the *Prinze Eugen* ("genuine Spaniard").

For that good piece of work, which saved a ship and her company and cargo (though later she was destined to be sunk) the Marconi Radio Officer received both the thanks of the owners and the M.B.E.

When a merchantman was torpedoed or shelled into a sinking condition by enemy raider or U-boat, the Radio Officers always followed a certain routine.

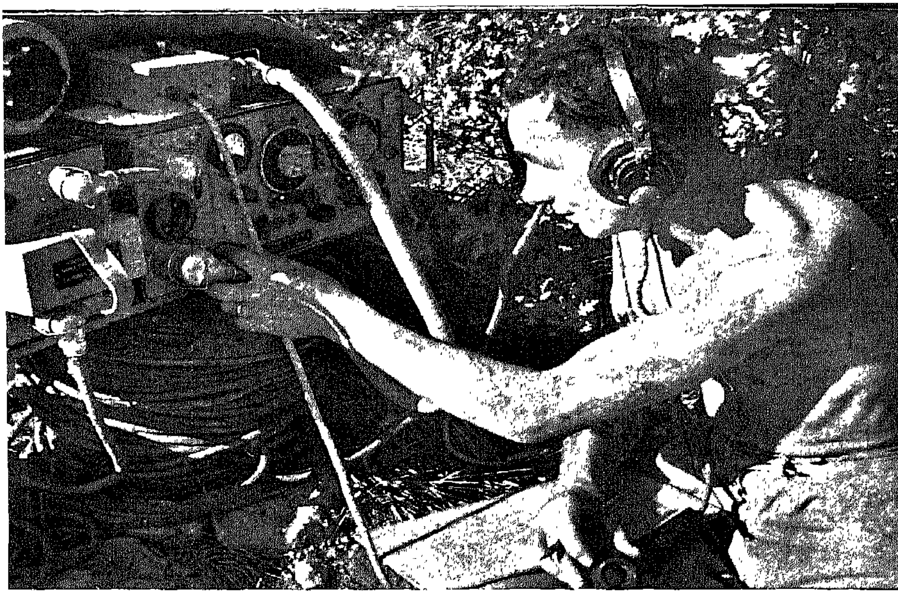
First, they transmitted to the last possible moment, and then, taking each a neat suitcase from a place of concealment, they joined their shipmates in the boats.

The ship sunk, the raider steams away, or the U-boat submerged leaving the ship's boats alone on an empty sea.

It was then that each Radio Officer opened up his trim suitcase and began transmitting before the astonished eyes of his fellow castaways.

The Marconi Company made these small suitcase sets, they also made the so-called bread-and-butter sets that were used in naval small craft, M.T.Bs, M.G.Bs, for inter-convoy communications and for communications between ship and ship, and ship and base.

It has been remarked that many Marconi Officers lost their lives on active service. The total at the end of hostilities had reached the figure 956 of the total 9,048 who served at sea. In addition, eight men are still listed as missing, and may well be added to the total lost; while twenty-seven suffered as prisoners of war, and 585 were disabled as the result of enemy action.

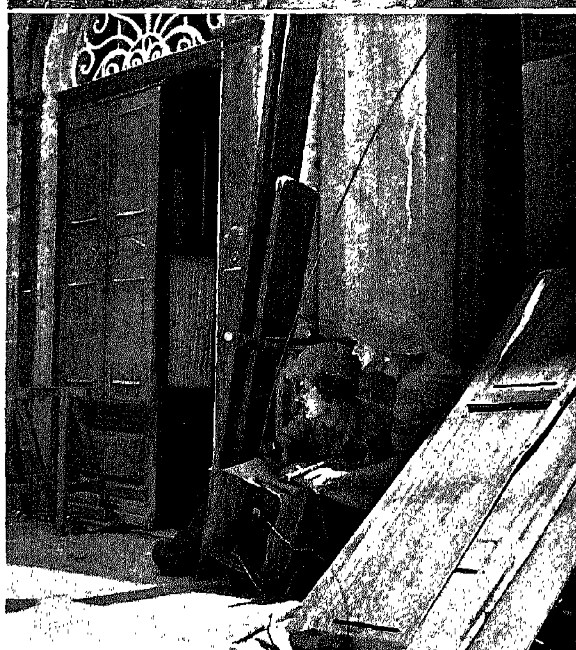


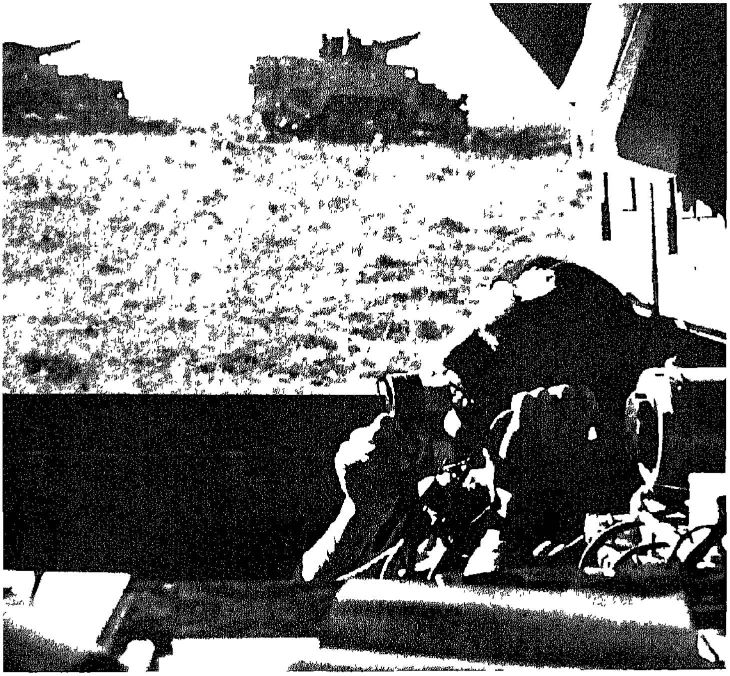
From an Air Observation Post is radioed the location of an enemy gun battery . . .

A study in concentration

He is Wireless Operator and, believe it or not, his name is Morse!

In the street fighting in Italy, Wireless Set and Tommy-gun form a useful partnership





In the midst of the battle the Wireless Truck talks while the guns roar . . .

He is wounded; but the message goes through

IV

THE BATTLE OF THE MEDITERRANEAN

EMPIRE LIFE-LINE

Though the Battle of the Atlantic and the Battle of the Mediterranean were contemporaneous, they are not comparable in many respects.

In the first, the real task was the conquest of the U-boat and surface raiders, which accomplished, this historic sea-lane was comparatively secure to our vital shipping.

The Mediterranean, a land-locked sea, and one equally vital for Empire communications, was vulnerable from the air from the day Italy declared war. And the ensuing ding-dong battle that was fought out on those blue waters was largely determined by the air arm, though, it should be added, such actions as Matapan provide material for the true perspective of the relative roles of air and sea.

That Battle was largely determined, too, by the success of our scientific and technical workers, and by the brilliance of offensive and defensive stratagems worked out by them and applied with dramatic success.

VITTORIO VENETO

On 27th March, 1941, air reconnaissance wirelessed reports that Italian cruisers were at sea south-east of Italy. Next day, by the same channel, came news that the battleship *Vittorio Veneto* and a large number of other warships were steaming south of Crete.

The naval action which resulted from that encounter between this Italian Fleet and the British Fleet under Vice-Admiral Pridham-Wippell, was notable for several features, of which the long sea chase of a coy enemy was one, and the persistence with which he was bombed by aircraft was another.

But for the defeated Italian Admiral it was neither of those battle factors that was uppermost in his mind in the moment of defeat.

"The British Fleet," he observed, "must have had very good radio advice. It would never be safe for the Italian Fleet to risk further encounters with the British Fleet in conditions of darkness and low visibility."

As we know, the Italian Fleet never did in fact oppose the British Fleet again in these waters, or anywhere else.

This episode in the Battle of the Mediterranean provides an excellent example of perfect apparatus in the hands of completely-efficient R.A.F. personnel and naval ratings.

For the Company, its interest is a two-fold one. First, much of the apparatus used was Marconi designed or Marconi manufactured, or both; secondly, some 2,254 R.A.F. crews were men who had been given the special war-time course in the use of Marconi equipment specially designed for their use in the Marconi College, Chelmsford.

"CHASE ME CHARLIE"

Towards the end of 1943, British and American ships in European waters were persistently attacked, and often sunk by gliders and bombs controlled by radio from a bomber plane.

These attacks occurred most frequently in the Mediterranean zone and were regarded by the Admiralty as a method of attack to be taken very seriously. It was by this method that H.M.S. *Barham* had been sunk, and several lesser craft, and it was clear that something had to be done to counter the danger.

The "Chase me Charlie" set-up was fairly simple. A master bomber, with special radio equipment for the wireless control of its Robot-planes, each carrying a torpedo, operated astern of the ship to be attacked, generally from a distance of around thirty thousand feet.

The receiver on the "missile" or Robot plane, had a superhet circuit, with crystal-controlled first oscillator, and an intermediate frequency of 3 mcs.

The controlling, or "master" plane, could use one of some twenty frequencies in a 4 mcs. band around the 50 mcs. region. To create confusion, the enemy transmitted from land stations other signals, so that no interceptor could tell which signal was actually controlling the missile or Robot plane.

That was a problem in remote control as it was put to the Marconi Company for solution by Aid to Surface Vessels.

When it is added that the intermediate frequency circuits of the receiver were sharply turned so that any jamming signal had to be very close in frequency to that of the master plane, the apparent hopelessness of the problem will be apparent.

Nevertheless, a small team of specialists was set to work at once. And eventually those workers produced the remedy.

A COMEDY IN REMOTE CONTROL

The specialists found that the enemy had been, perhaps, a trifle too cunning, and they at once took advantage of the excess of that attribute in him.

It was found that the high frequency circuits of the receiver would respond to any frequency in a narrow mcs. band, and that, consequently, it was not necessary to change whichever of the twenty possible controlling frequencies that was being used at any given time.

The selection was done in the intermediate frequency circuits, the crystal controlling the local oscillator in the receiver being slightly different in frequency from that in the transmitter of the master plane.

Thus, if two jamming signals in the pass-band of the high frequency circuits, and separated by that difference, reached the receiver aerial, they were passed to the mixer and produced a beat which passed through the intermediate frequency circuits of the receiver and had the same effect as a signal within one part in 30,000 of that of the master plane.

Thus the highly selective receiver circuits used by the enemy proved to be of no avail in preventing jamming.

This was the solution of the problem and, thereafter, the lower deck spent no more exciting moments watching the approach of the radio-controlled flying-bombs which they had christened "Chase me Charlies."

Thereafter we were able to do a little remote controlling too and so "Chase me Charlie" took to making sudden dives into the sea no doubt to the bewilderment of the pilot of the master plane.

One of these torpedoes descended on the Island of Corsica where it failed to detonate and was later examined by Marconi experts who extracted from it the secrets of its mechanism.

And later again, the equipment of a master plane fell into the same hands. These two pieces of good luck gave the Marconi technicians complete knowledge of one of Germany's cleverest radio war weapons.

The Company was called on to produce at short notice some thousands of the special transmitter designed to send the robot-planes into the sea.

As each set weighed three-quarters of a ton, and the top priority order came at a time when the Company was already working full stretch, delivery at the rate of five sets a week in less than six months was regarded as a production achievement.

The circumstances that the Company had to rent a large roller skating rink for the assembling of this set in order to cope with the pressing demand—throws an interesting sidelight on the febrile conditions under which much of its war production was carried out.

The whole of this "Chase me Charlie" job was done by the Marconi Company, and the scientist whose hand guided the whole enterprise was that of a senior member of the Company's Research Staff, then with the Admiralty, and now back at work in his laboratory at Great Baddow.

THE SUPERSONIC BUOY

Frequently it happened during the War that scientific work was entrusted to the Company by the Admiralty without any information as to the object of it.

Thus, on many occasions the scientific and technical side were engaged on projects on terms somewhat similar to those upon which subscribers to a certain South Sea Bubble Company were invited to part with their money: "For a great project, nobody to know what."

The three members of the scientific staff who travelled at the invitation of the Admiralty to a secret laboratory one day in January, 1942, found themselves in that position.

They were asked to consider the possibility of a submarine buoy which would radiate supersonic signals, with a range of four to five miles, which would be sufficient for bearings to be taken on, but would also be incapable of being picked up by the enemy hydrophone equipment.

Further, this projected buoy was to be so devised that the enemy would be unable to fish it up if laid in his waters; against which contingency and the possibility of the buoy breaking loose from its moorings, it was to be fitted with a *hara kiri* device for blowing itself up.

Next, the buoy was to be so mechanised that it would transmit only at set times, and it was to be capable of radiating different pulsing rates to prevent identification by the enemy. And, last, the buoy was to be devised to have a running life of three months, and to be provided with a clock which would keep time to within half an hour in that period, and was to transmit every one or two hours, day and night, but for only fourteen days in the twenty-eight.

A WRANGLER'S HEADACHE

The supersonic buoy, as thus presented, looked very much like a Senior Wrangler's headache. So that it was not very surprising that when the first model had been completed, it proved itself to be a "bad buoy" when dropped overboard from a naval craft in Barnstaple Bay.

Three test buoys had been laid and anchored on the sea-bed. Then, three days later, when they were recovered, one cable came up without its buoy. A depth charge was therefore dropped on the missing buoy which was washed up three months later on the foreshore, an object of public suspicion and of police activity.

Further tests were carried out by the Company's scientists in May, off Felixstowe, from a minesweeper, primarily to determine the buoy's range, the suitability of the signals, and its general reliability.

It was then established that the range was upwards of four to five miles when the receiving vessel was hove to, and about three miles when steaming at ten knots.

Several details had to be attended to to assure that the buoy would not drag its moorings in a tideway, or be tilted from the perpendicular, so that the horizontal radiation would not be impaired.

These difficulties were overcome by the bridal tackle, and the buoy was put into production, sea-trials taking place 1st-3rd October, 1942.

"A GREAT PROJECT"

What, then, were these buoys intended for and what might be the connection between them and the Battle of the Mediterranean?

To-day, it is permissible to answer both questions.

The purpose of these truly-remarkable buoys was to act as radio underwater light-houses for submarines navigating in enemy-mined waters.

They were laid by surface craft in information from high-flying aircraft for whom the channel through the mine-fields was rendered visible by height.

The buoys were first used in the invasion of Sicily to guide transport and beach-landing craft on to the beaches, such craft being equipped with wireless to put out signals.

The buoys had been developed by the Company (it had a secret department where naval models were made and tested) to the point where a model was evolved that could be fired from the torpedo tubes of a submarine at periscope depth. And this model, the Mark II, was used and proved very successful, not only for the Sicily landings, but at Anzio also.

The later use of the buoy may well have had its origin in a makeshift device which was used during the preparations for the landings on the beaches of Sicily. There the buoys were needed to guide in the radio-equipped landing craft to their appointed positions on the beaches. The difficulty arose of getting the buoys laid without arousing the suspicions of a very nervous enemy. The usual method of laying from motor-launches was out of the question, it was therefore decided to use submarines.

The supersonic buoys were lashed to the submarine casings and taken in at periscope depth to the shallow waters. There the submarines surfaced, unlashed and laid the buoys and submerged, all by the bright light of the Mediterranean moon.

Another job done by the supersonic buoys was at the time of the midget submarine warfare in the English Channel and on the North Sea routes. They were then used to mark sunken wrecks and thus to prevent submarine craft wasting time and depth-charges on wrecks picked up on their Azdic gear.

But perhaps the most important work performed by these remarkable scientific buoys was that done on D-Day, which will be related in a later chapter of this book.

THE GOLDEN ARROW

When the actual Sicily landings took place one of the first vehicles to be put ashore by landing craft was the Marconi-equipped mobile wireless unit. Known among the Company's people as the *Golden Arrow*, this complete unit comprised seven vehicles capable of transmitting or receiving over long distances at high speed and with minimum of time-lag in erection.

The unit was made up of two Bedford-Scammell vehicles for transmitting and receiving, two power-generating sets with Lister four-cylinder oil engines and dynamos mounted on trailers, each drawn by standard four-wheel-drive Army lorries. And, last, a car for the officer in charge.

This unit was put ashore very late that night, but by 9 a.m. it was operating and communicating with the War Office.

(*En passant*, the Eighth Army used the *Golden Arrow* unit for communications between Cairo and H.Q. in Tunisia.)

The troop leader reports back to H Q. by radio

A MISFORTUNE OF WAR

Early in 1941, Lord Wavell decided that Palestine needed a wireless telegraph station, and put through this urgent message: *Telegraph station must be here by April.*

The Mediterranean at that time was about as unhealthy as it could be for our shipping, and it was consequently decided to take no chances, but to reduce risk of loss at sea to the minimum.

The transmitters for Palestine were therefore shipped in one ship, the masts in a second, the accessories in a third. As for the engineer who was going out to do the job, he sailed in a fourth ship.

All three ships carrying the Palestine telegraph station were sunk in the Mediterranean by enemy action. And the ship in which the engineer travelled was captured and the engineer taken prisoner.

Some days later, a Catalina on reconnaissance, spotted a suspicious craft steaming off Bordeaux. He immediately called up a destroyer on his wireless. The enemy ship was duly captured when, among the four hundred prisoners aboard her, was found the Marconi engineer, sole survivor of the costly enterprise.

AND A CONTRETEMPS

In the same year the Company was asked to instal a wireless station at Gibraltar. At first it was decided to instal the equipment aboard a ship in the harbour. Eventually, the installation was carried out on the Rock itself where it has been functioning continuously ever since.

At Malta the Company installed underground a H.W.T.A. Concentric feeder change-over system. Having by that time bitter experience, it was decided to transport this equipment by submarine.

The apparatus was made and cased and despatched to the port where the submarine awaited it. But, alas, it would not pass through the submarine's hatch. This caused much trouble and some delay. But difficulties were eventually overcome, as they usually were in the days of the War; the enemy-infested sea lanes were safely navigated, and Malta got sixteen transmitters, all installed beyond reach of the rain of bombs which was to beat so mercilessly upon that gallant island for so many weary months.

DESERT WAR AND WIRELESS

The complex organisation of a great army, backed by a great air force and spread through the chaotic wastes of a vast desert, is made possible only by efficient signals—cables, dispatch riding, but, above all, by wireless. Without completely organised signals of all kinds, the force of soldiers and airmen who pushed the Germans back into the sea from Egypt to Tunisia, would have been deaf, mute and helpless.

A Mobile Wireless Van in the Western desert

In the desert they are learning to use their radio sets

One of the most useful units on the wireless side of Army Signals was the mobile wireless van. These vans, using Morse at about thirty words a minute, had a range of a thousand miles and were equipped to stay a long period in the far desert without replenishment of water and foodstuffs.

In our forward movement across the desert our light armoured brigades, with infantry and tanks, covered the soft sand or salt marsh in forces organised in columns of guns, with infantry to protect the guns, and squadrons of armoured cars and "Honey" tanks.

Without wireless communications this organism would have fallen to pieces within a single day and for that reason it was close-knit with wireless equipment throughout. It is when one learns that every Division in the field in Africa had a Royal Signals Unit over 700 strong, with 200 vehicles, many equipped with wireless apparatus whereby the Commander and his staff are enabled to keep in touch with every single unit and all services and with the headquarters of

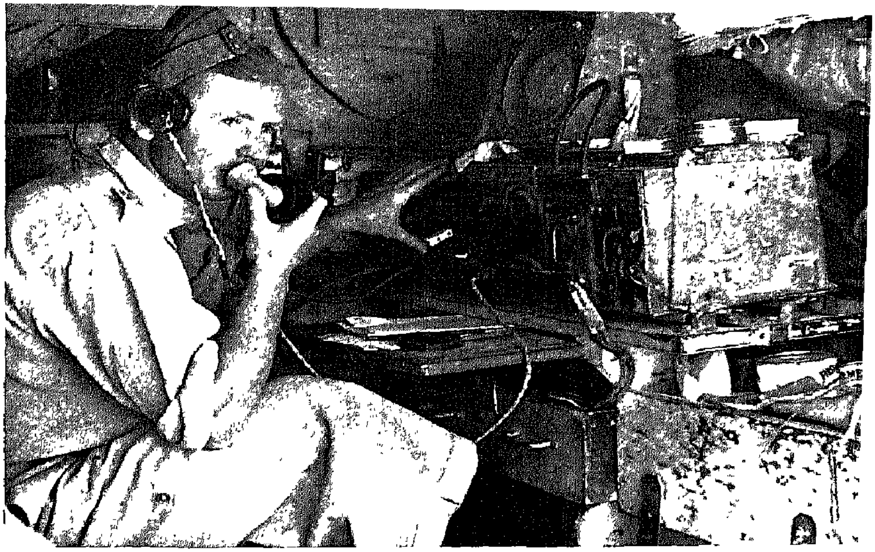
other army formations, that one has a complete picture of the role of signals and of their scientific development.

Soon after the war in Africa began the Long Range Desert Group was formed. Its purpose was to act as guides to other units travelling against an enemy concealed somewhere in the uncharted desert wastes.

This group made great reconnaissance patrols, often well into enemy territory, sometimes it guided and even transported special troops who carried out those spectacular raids on enemy airfields which were the dramatic highlights of the desert war.

The use of wireless by this formation was no simple thing. It was used, in the first place, as sparingly as possible and only when something really important was spotted that needed to be reported back to headquarters. Then only the briefest use was made of the wireless car, which moved off into the desert several miles before transmitting, as precaution against the enemy's direction finding.

An armoured Wireless Car in the Western desert



A Signaller, he knows of the distant battle only by radio .

A FANY at Special Operations H.Q , Italy, receives a message from the field

Yet without wireless the whole of this technique of reconnaissance would have been impossible. For the Marconi Company the enormous development of wireless for military purposes has more than a technical interest; it possesses historical associations which are a reminder that it is now close on half a century since Marconi sent his first signals through the ether.

A BOER WAR MEMORY

The first wireless unit to participate in war was one organised by members of the Marconi Company staff for service in the field during the Boer War. Kites and balloons were used and a certain degree of useful wireless signalling was done. Using bamboo aerial poles, and Cape carts for transport, the range achieved on the veldt reached twenty miles, and, once or twice, up to a hundred miles. The Royal Navy also used it and wireless did useful work during the blockading of Delagoa Bay, and one or two blockade runners were caught by means of it.

During the siege of Ladysmith members of this Unit offered to make a dash for it with their apparatus so as to establish communications with the outside world from within the beleaguered town, but the offer was declined.

The interest of this retrospect, of course, lies in its historicality, so that it may be said perfectly truthfully that Marconi wireless apparatus and personnel have been employed by both Army and Royal Navy since 1899. The claim may be added that since 1902 the Company has also continuously serviced the Merchant Navy, for in that year both *Campania* and *Lucania* were Marconi equipped.

V

THE BATTLE OF THE PACIFIC

"THAT GREAT COMMON"

Nelson's biographer, Admiral Mahan, referred once to the ocean as "that great common"; and how great it is the immensities of the Pacific Ocean reveal.

Twelve hundred miles separate Borneo from Burma, three thousand divide New Guinea from Japan. It is four thousand five hundred and twenty-one miles from Yokohama to San Francisco, or twelve days' sailing, and seven thousand six hundred and ninety-two miles from Sydney, Australia, to Panama.

No map can convey to the imagination the vastness of this expanse of islanded waters over which was fought out the Battle of the Pacific. For a map, though it may produce a mental image, an idea, cannot evoke the spacial reality.

It was a battle so far flung, indeed, that only wireless communications made possible its grand strategy and the solution of its unnumbered tactical problems.

Nor was the sole problem involved that of space. Climate also conditioned the course of events, reacting both on the men engaged and the munitions and materials with which they fought.

Some of these problems were brought to the engineers and technicians of the Company for solution; and they were duly solved at office drawing board or laboratory bench on the Company's premises at Chelmsford, or elsewhere.

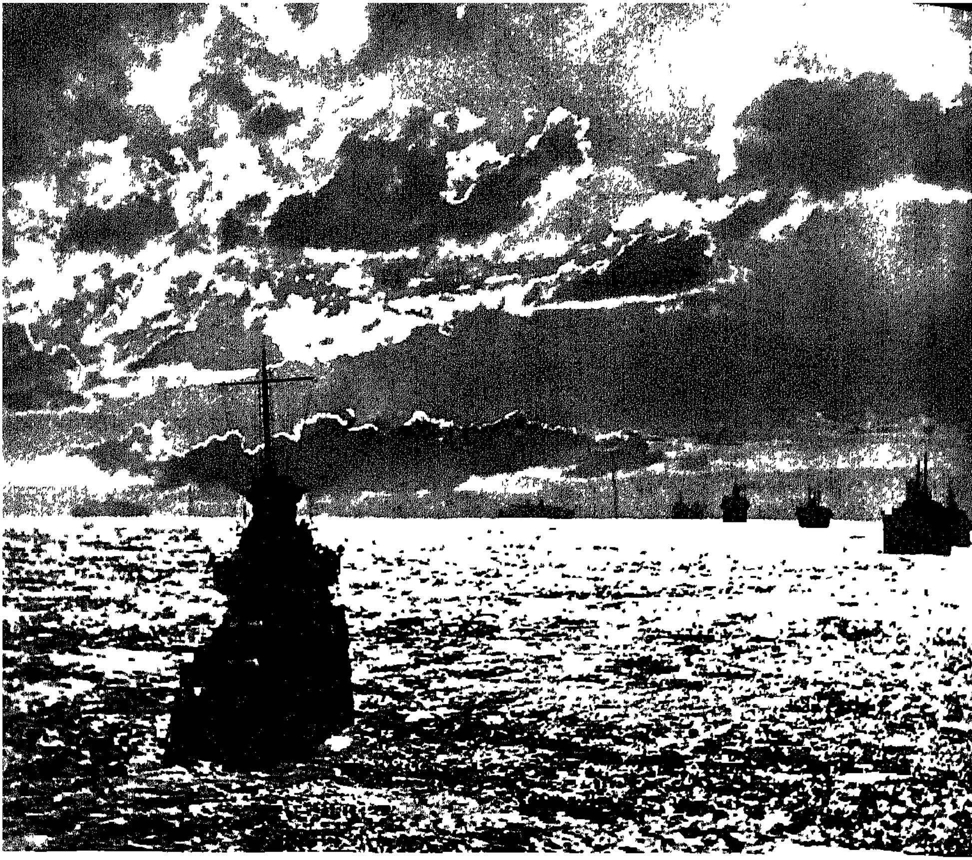
THE BLIND APPROACH BEACON

To pilot a fast-flying Swordfish out of the high Pacific air down to the heaving deck of the aircraft-carrier that shows up only as minute blemish upon the blue surface of the ocean, is a considerable feat, even with good visibility and a calm sea. Consider what it involves.

There must be close co-operation in which pilot and deck-landing-control officer, ship's crew, and manoeuvring navigator must perform faultlessly to achieve that fine degree of precision that is the essential element of the whole feat.

First, the aircraft-carrier must put her head into the wind so that the homing aircraft can land into it. But the navigator must beware in so doing that he does not blind the pilot with his smoke. And so he must keep his ship's head just a trifle off to starboard.

The pilot, as he approaches, first hears, and then sees, the control officer, whose voice is wireless-borne to his crowded cockpit. Presently, he sees the small figure with outstretched arms that hold the two circular fans, the "bats", which are to guide him in.



"That great Common . . ."

And in a moment, with luck, hook grapples arrester-wire, the machine is on deck, and the trick is done.

In the Battle of the Pacific aircraft-carriers assumed a new importance. Without them the battle could not have been fought, as it was fought, for these great ships, carrying each its aerial stings, enabled us to strike the Japanese even to the remotest corners of the Great South Seas.

So, inevitable, it was asked: Have we the best that science can devise to see our pilots safely home at sea?

In due time the answer to that question was produced by the Marconi Laboratories at Writtle, near Chelmsford. It took the form of the now-familiar blind approach beacon: and it revolutionised the sea-landing of aircraft. . . .

HAPPY LANDINGS

The Swordfish pilot, his mission completed, is flying home It is a moonless night, visibility is poor, and the Pacific Ocean below is a great pool of dark. The pilot begins to lose height, flying with confidence, however, his eyes on his instrument board.

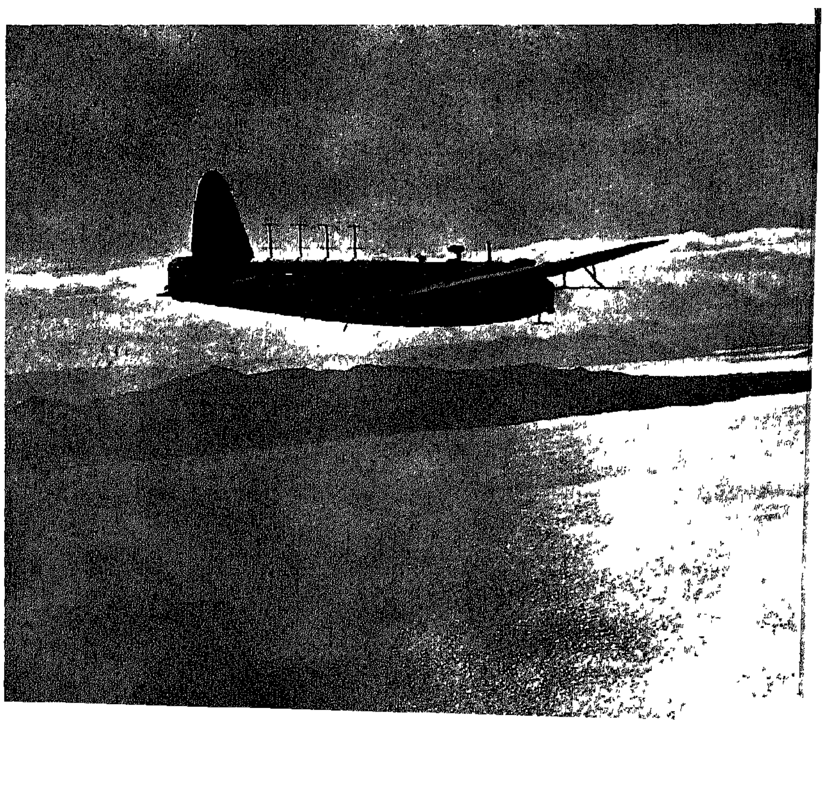
He is steering by signals, easing his course a little to port, a trifle to starboard, in response to the signals which are coming to him telling him when he is flying precisely on the invisible aircraft-carrier's fore-and-aft line, or when he has port or starboard deviation.

He is still eight miles astern, but he navigates along this invisible guiding line that presently reveals the ship's stern dead ahead of him. This pilot has no course correction to make, for the blind approach beacon gave him his course already when he was eight miles distant

And so, despite darkness, fog or cloud, the aeroplane, homing to her carrier, now follows the radio guide and lands safely on deck

The blind approach beacon is now standard equipment. It represents one answer made by the Marconi Company to a battle hazard. There were many others.

A Wellington Radar-equipped



JUNGLE RADIO

The late Major General Wingate once said: "I can always persuade even untrained troops to rely entirely on wireless in the jungle."

And he added that his famous Chindits throughout that terrible campaign put their trust in jungle radio in all Long Distance Penetration.

Wingate's jungle war technique was, actually, based on, and made possible by, an efficient supply of wireless apparatus capable of withstanding the frightful conditions of jungle warfare.

Imagine England clothed in almost impenetrable malarial tropical forest spiked by ranges of unscaleable mountains, watered by swift, unbridgeable rivers, and imagine next an enemy operating from bases in Scotland, and an attacking force striking upwards from the south with bases in Asiatic Russia. and you have a rough-and-ready idea of the Burma battlefield set-up.

It imposed a form of warfare in which only small numbers of men could be used for the offensive. And though the nominal front was seven hundred miles in length, the Long Range Penetration technique, that is, an advance along a single axis of the supply line, was the only feasible *modus operandi*.

Such a battle technique, as worked out first by Wingate, gave field wireless communications supreme importance for the many small groups of jungle-isolated men.

Those men of the L.R.P. groups worked their Marconi sets often under such bizarre conditions as under blankets by torchlight for fear of lurking Japs: while the men at base often worked twenty-four hours on end. The temperature was often 100 degrees in the shade and 165 degrees in the sun, with a 80 to 90 per cent. humidity. And in the jungle lurked all those agencies of Nature that apply themselves ruthlessly to the elimination of man and all his works.

THE CLIMATIC FACTOR

On the superficial view such matters may seem no direct concern of the manufacturer and designer of radar and radio apparatus. Yet how, without a thorough knowledge of the conditions under which the apparatus will be used. can the appropriate equipment be designed and made?

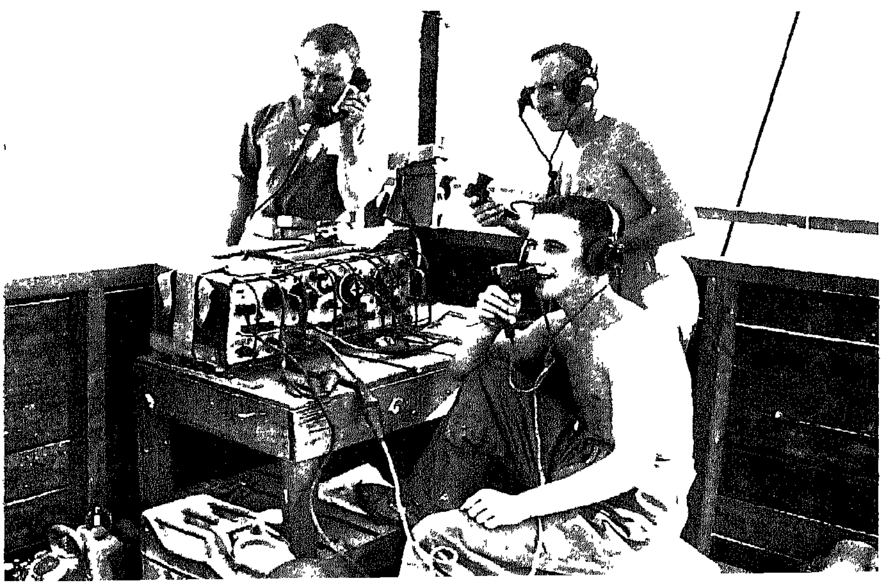
For example, among many other meticulous tests and precautions that came to be standard procedure in the manufacture of apparatus destined for tropical service, even the crystals were subjected to extremes of temperature under laboratory conditions.

If the jungle blew no actual hot and steamy breath on the Company's Chelmsford technicians, it certainly thrust on them a considerable number of curious jungle problems. It was upon the successful solution of these that the efficiency of apparatus, as vouched for by Wingate and his Chindits, entirely depended. They were mostly quite commonplace problems, though so much depended upon the right answers to them. There was the puzzle of how to

From a Burmese temple the wireless message goes out

The Army takes the Burmese village, the Wireless directs the R.A F. which flies up the food and equipment

In the Pinwe area, Northern Burma, duing the advance of the 36th British Division



pack and protect apparatus that had to make a journey of many thousands of miles, so that it would arrive neither slightly damaged nor completely fragmented.

Again: How were the common jungle enemies and jungle hazards to be circumvented—the excessive humidity, the ruthless attacks of white ants, fungi, verdigris, water?

It was in such ways, as the land war developed in the Eastern Hemisphere, that the behaviour of wireless apparatus under tropical conditions became a matter, both of scientific interest and practical and immediate war urgency.

General MacArthur likes to tell the story of the part played by wireless in war, and, in particular, of that occasion when a weak radio signal, located in the island of Panay, heard in the Autumn of 1942, led to first moves against the Japanese in the Phillipines and to later full-scale invasion.

"That radio signal," he said, "weak as it was, lifted the curtain of silence and uncertainty, and disclosed the start of a human drama with few parallels in military history."

TROUBLE IN TRANSIT

Soon after the opening up of the Burmese Campaign, reports began to trickle in to Chelmsford with monotonous regularity. They told of valuable consignments of wireless apparatus and radio valves either damaged or ruined completely in transit, or while in use under tropical conditions.

Sometimes the loss reported was as high as eighty per cent., and, in addition, there were losses caused by enemy action on the high seas to be brought in to the total picture of wastage.

Thus, one way or another, the percentage of the achieved output to reach the fighting man and thus to become effective was dishearteningly low. And it was plain that something had to be done about it.

This was the time of the Washington and Quebec Conferences of August, 1943—misread through lack of knowledge of Allied strategy as presaging an immediate intensification of amphibious operations in the Pacific. They were to come, but later. The decisive factor at that juncture was, as we now know, the withdrawal of all available craft from the East to the Anzio operations.

It was when the campaign that was to bring glory to the Fourteenth Army opened up that these technical troubles became a real challenge to the ingenuity of the Company's scientific staff.

Most wireless apparatus requires careful handling, though it will often stand up to a good deal of rough usage. But much radar equipment is really delicate and calls for very careful handling.

Radar cannot be shipped immense distances, or for that matter even short, unless it be kept the right way up.

A packing case or box may be stencilled before leaving the Marconi Works: *This Side Up*; but that injunction may mean little or nothing to the men who will man-handle that package at the other end of a long sea haul.

This cause of much loss was overcome by employing a simple device. Radar equipment was packed in stout wooden boxes, provided with curved wooden battens similar to the rockers of an old-time cradle, along their sides. No new idea, it is true, but a new application. Thus the boxes remained upright in transit for the same mechanical reason that an egg lies upon its side.

A radio valve is a masterpiece of such exquisite design and workmanship that it achieves beauty unawares: at the cost of fragility, however.

All radio valves leaving the Marconi Works have always gone snugly housed in a fitted canvas bag or cradle, hung suspended from springs and contained within a strong wooden box.

Such methods of packing eliminated a big percentage of the losses consequent upon the older methods of packing.

JUNGLE v. RADIO

Wireless apparatus in service in the jungle felt the climate as much as our sweating and mosquito-tortured troops.

The two main enemies were tropical humidity, and jungle fungi. The first attacked materials, the second affected function.

For some time the first difficulty seemed to be insuperable. Many experiments were made, but none yielded the sought-for solution. Then there arrived back at Chelmsford one of the Company's staff who had personal experience of New Guinea, having just returned from there. He told how men in the Tropics were surmounting this difficulty. They were, he explained, keeping components dry by storing them in jam jars containing silica gel—a chemical that absorbs moisture.

"Where did they get their silica gel?" he was asked.

"From aerial engine cellophane wrappings," he explained.

The fungi pest, which interfered with transmission, was finally countered with varnishes containing a high percentage of such fungicides as penticolphenol.

But it was not always quite so easy as that.

Sometimes the right remedy was found, only to be beyond reach because of priority elsewhere. That was the case during the search for a good proofing material. It was found that chromium, or cadmium and chromium, gave excellent results. But both were high priority for other purposes. Thus substitutes had to be found for both. Zinc eventually proved to be perfectly efficient for this purpose.

Thus, little by little, the worker in the laboratory lessened somewhat the trials of the fighting man in the jungle, banishing verdigris from brass, corrosion from aluminium and plastic materials, decomposition from mirror surfaces.

Throughout the Burma Campaign, Chindits carried Marconi 20-Watt transmitters and receivers, the appartus which earned the high encomiums of Wingate and his men.

These sets were specially encased for this work in metal and made absolutely water-proof, so that they remained in perfect working order, even after immersion in twenty feet of water for considerable periods.

A JOB IS WASHED OUT

There were occasions during the War years when the government passed to the Marconi Company, sometimes a bare idea, at others, merely seminal suggestions, with the request for a thorough exploration of all patent possibilities in them.

When this happened, at once teams of men with the appropriate knowledge and experience began research and experiment.

In the early days of the War, when such challenges to the skill and ingenuity of the Company's people were much more frequent than they became during the final years, the hours worked were indeed prodigious. And, with so much depending upon success, there was present, also the element of nervous strain.

In those days of high-pressure, anxiety and tension, working often under air bombardment, people on the scientific side had much to contend with.

Conversations such as the following were then not infrequent.

Chief: "Here, look at this, the Admiralty want us to work it up."

Engineer (studying chit): "Yes, m-yes, I think I see what he's getting at. But what's it going to be used for? What's the big idea?"

Chief: "Not a notion, my dear fellow, it's a top secret."

Now, it is not the easiest thing in the world to work out a fragment of a design without knowledge of the whole. It is like asking a man who has never seen a bicycle to work up from a rough sketch the three-speed gear component of the machine. But that, in effect, was what the Company's engineers were obliged to do many times during the War, such was the secrecy imposed by security.

Seen in retrospect, that apparent excess of precaution has been fully justified. The Empire never fought a war in which there were fewer leakages of technical information to the enemy's Intelligence than in the War recently ended. Particularly in the case of radar was secrecy preserved at an exceedingly high level.

In such cases as that indicated it was not until all parts of the secret apparatus had been worked out and manufactured by a number of industrial concerns, over which production had been spread, that assembly at the central secret factory disclosed the completed work and revealed the central idea of it.

Work on secret ideas sometimes kept a team of specialists hard at it for as long as a year and, in at least one case, for eighteen months.

And the finale?

Sometimes it was rather like this:

Chief: "You can pack it all up, you fellows."

Chorus: "What!"

Chief: "The job's washed out."

Such cancellations sometimes meant that the war, advancing in Time, and changing its shape on its course, solved problems of one moment to give birth to others of another. Sometimes it meant that a better alternative to a given problem had been hit upon.

But for the men toiling hours, day and night, for many months on end, and always with that consciousness that much might depend upon the successful issue of their work, such scrubbing was heart-breaking.

Yet, throughout the whole of the War period there never occurred a case where such set-backs affected the worker's morale, or engendered anything remotely approaching a defeatist attitude. On the contrary, the capacity of the Company's "back-room boys" to take punishment, and to come up smiling for more was quite admirable.

NAVAL RADIO EQUIPMENT

For the naval side of the Battle of the Pacific, among much else, the Marconi Company made much radar equipment. It also did development work, such as that on those types which will become effective in the future. This is the very powerful radar equipment for battleships, cruisers and fleet-carriers, its purpose to give the longest possible warning of the approach of aircraft.

Some idea of the complexity of such sets can be arrived at from the number of valves that go into them—*no less than three hundred.*

The demand for naval equipment was generally a top priority. Therefore, to achieve production on a scale, and at a speed, to meet the urgent needs of the Pacific battle zone, the Company sometimes accepted a pre-production contract.

Perhaps that term calls for a word of elucidation.

New designs pass through a pre-production phase, during which models are made and tested before large-scale production is begun.

These steps take time, particularly for the drawing office work to be completed. In the case of some types work was begun in the Workshops of the Development Department.

A SHADOW DAVENTRY

The decision by the Air Ministry to adopt the Company's mast system followed a visit of the Ministry experts to Daventry, where the whole erection is Marconi throughout, design and installation. And on the evening of that same day, the Company received by telephone a "crash" order for sixty masts.

As with many another "crash" order this was handled within the time limit set.

At that period the vulnerability of the great Daventry station was giving the authorities considerable anxiety. Its destruction by bombing would have

brought about very grave consequences, since it would have involved major interference with communications.

The Air Ministry consequently decided that it would be necessary to erect a complete "Shadow Daventry". Ramisham, a small Dorset town, was selected for this purpose. The work was entrusted to the Marconi Company.

Anyone who has seen the Daventry set-up will be able to form an opinion of the magnitude of the task of producing its "shadow" in a short space of time; for Daventry is the result of years of work and development.

The completion of the whole "shadow station" in six months is consequently a job about which the Company permits itself to be proud. It was a dramatic example of the strain of long hours, high-pressure and a prolonged period of strain.

But, even then, progress did not seem to be fast enough, and it was decided to take over a small factory for the job.

In that small factory, working in closest co-operation and in an efficiency-promoting intimacy very hard to achieve in a large Works, production of these sets was stepped-up in a way that would have seemed impossible in 1939, or even in 1940.

The amount of radio and radar equipment carried in a modern naval ship is enormous, and in the case of a battleship, may be as many as fifty transmitting sets and an even greater number of receiving sets.

So much powerful apparatus produces plenty of noise; and in naval craft, as the quantity of wireless apparatus and other radio or radar gear increased, "noise" became a serious problem.

This difficulty has been largely overcome by the technique of filtering, which was, before the War, somewhat haphazard, but has now been greatly improved.

VI

THE BATTLE OF GERMANY

INVASION

Prelude to the Battle of Germany, the invasion of the Cherbourg Peninsula was made a feasible operation only by years of preparation, by devices and stratagems known only to those who directed the great work, and by those who carried it out.

A watching world saw only a vast armada sweeping majestically to its objective in many thousands of large and small ships, beneath the greatest sky umbrella ever put over a military operation. Never since Xerxes crossed the Hellespont to invade ancient Greece in twelve hundred ships and with a million men, could history match this stupendous engine of war.

What the world did not see, nor could guess, was the diversity and magnitude of the preparatory work that had gone before. For into the building of that great operation had gone the work of many brilliant brains, many skilful hands and the superb, though unsung courage of men who saw neither beaches nor battles.

Long before D-Day, our Intelligence had been patiently gathering information direct from occupied France, and it was this steady flow of precise information brought back or transmitted by our agents that made the invasion of Europe something better than a good military, air and naval gamble.

From these reports, laboriously, bit by bit, London patiently articulated the whole picture of occupied France, Belgium and Holland, like some great jig-saw puzzles.

We knew the defence system of the West; we knew, intimately, the terrain, every fort and gun-emplacement; even the psychological state of the populations. We knew the great harbour of Cherbourg itself, down to the precise location of the meanest submerged craft sunk in the fairway.

It is possible that no great military operation was ever prepared with so great a degree of care, of attention to the minutest of details. And much of this work was made possible only by the exploits of men whose names will never be known, by men for whom failure meant ignominious death, and success nothing beyond the personal satisfaction of duty well done.

"Yet, amazing as it may seem," said an Intelligence Officer, "our great difficulty was not to get men for such work, but to make our choice from the many who volunteered."

CLOAK AND DAGGER

Cold courage has many degrees, but few, surely, higher than that required by the man who steps out of the shadows of night to board the waiting aeroplane that is to drop him by parachute in the heart of enemy-held territory.

Clearly, such fine men were entitled to the very best equipment that could

be put into their hands. And to the Marconi Company was entrusted, early in the War, the designing of a portable wireless apparatus suitable for this work.

Because it was known to those who made them that these sets were designed for the use of our secret agents, the job became known among the people under the code name "Cloak and Dagger".

These were the men who kept our Intelligence informed on the underground movements, the saboteurs and go-betweens, the men whose work was only possible with the connivance of those who were prepared to risk savage reprisals to shelter them.

Two types of sets were required. One that could be housed in what to outward appearances was an ordinary suitcase. The other, even smaller, was designed to go into an attaché case.

What had to be envisaged were the conditions under which the user would have to operate. This was, more often than not, in some lodging in a German-occupied town where the sole facility for an aerial was either picture rail or curtain rod. The sets, though so small, had to be devised to provide maximum range. The transmitting keys had to be fitted with a device for muting the tell-tale click which might betray the transmitter.

The attacheé-case set—a very small one—contained a transmitter and receiver working on short waves with crystal control. By means of it, our agents were able to communicate with England.

Without such means of communications the work of men—and women—operating under conditions deemed by many as imposing the maximum endurable strain on heart and nerves, would not have been possible. And thus information of activities in enemy-held territories would have been considerably less complete than was the case.

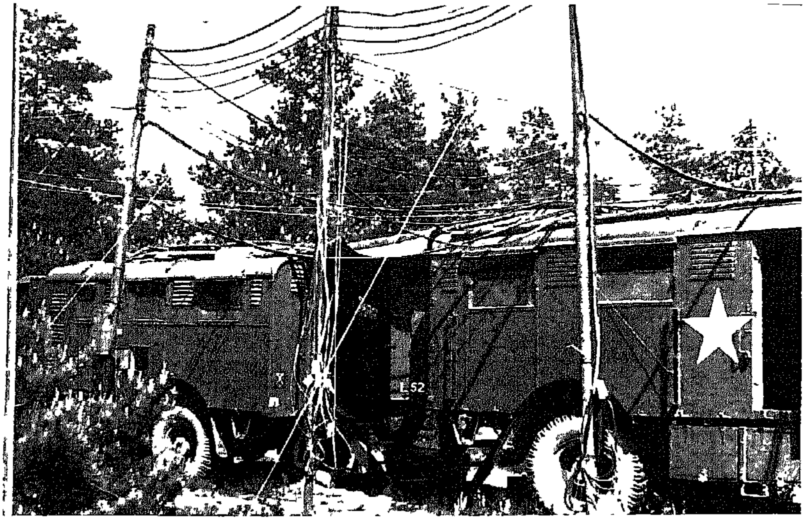
Even now, when the War is over, but little had been told of the heroism of many who, perforce, must remain anonymous.

On the technical side, this particular work had an interesting and important sequel. The Company's interest in the industrial processing of crystals had been stimulated, and a large department was ultimately brought into being to develop the work.

Presently something will be told of the Marconi portable set as it came into use after the beach-landings had been established, and the Battle of France was beginning to fan out over the fat Norman land, bringing daily nearer that final battle which was the Battle of Germany.

LISTENING BOATS

For twelve hours a day, the Royal Navy "listened" to Cherbourg Harbour; and what they heard went down on large-scale hydrographical charts. Survey boats, known colloquially as *Listening Boats*, carried out this work, taking fixes at intervals until the Echometer chart of the Harbour marked the position of every sunken ship and every obstacle to navigation.



At the Tactical H.Q. of Field-Marshal Montgomery, C. in C. 21st Army Group, where the German Army in North-west Europe surrendered. The picture shows the Signal Office vehicle and a second vehicle carrying a 40-line telephone switch-board and test frame

Measuring only 12 inches x 12 inches x 8 inches, this set was powerful enough for communication to England from the Normandy shores. It was also the Arnhem men's last link with Britain and the means by which the newspapers received reports from their correspondents with the 1st Airborne Division

This instrument, manufactured by the Company under its own patents, was supplied to naval craft in large numbers.

The Echometer is a navigational aid originally designed for the purposes of peace, which are very wide, but which proved itself equally valuable in war.

The principle of the Marconi Echometer is echo, or reflection. It is based upon the observed fact that if an underwater sound impulse is emitted from a ship, it travels outwards through the sea at a very rapid rate, and at a uniform speed. On reaching the ocean-bed, a part of that impulse is reflected and returns to the ship as an echo.

The velocity of sound in sea-water being known, by measuring the time between the emission of the sound and the reception of the "echo", the depth of the water can be determined.

Echometer impulses are transmitted and the echoes transformed into visual form by an indicator that automatically registers the soundings, working on the principle of an oscillograph, coupled with a deflecting mirror. A sounding received as an echo, produces a peak point on the calibrated scale, thus giving the exact depth.

The Marine Marconi Company has fitted 1,200 trawlers with Echometers, and skippers have made the interesting discovery that by means of it they can secure echoes that tell them of the presence of shoals of fish.

This instrument played an important part in the Invasion of D-Day, but when the day come its work was done.

THE ELEMENT OF SURPRISE

By D-Day all ships were radar-equipped. A radar survey had been made, and the Royal Navy supplied with charts showing every enemy radar station from Norway to the Atlantic seaboard.

Thus, what had started out in life in the early days of the Battle of Britain in a small van perched on the South Foreland had become a considerable organism, and one with a big D-Day job.

Here is one example of what that job was. Some time before the Invasion, we assembled a decoy fleet off Dungeness, and by putting over a terrific radar jamming, completely hoodwinked the enemy and threw him off his guard to some extent.

That jamming was organised by a Marconi man serving temporarily with the R.N.V.R., the same who had played that strange game of hide-and-seek across the Straits of Dover some account of which has been given here.

It was this same unit that equipped the gallant minesweepers that lead the way in with hearty radar jamming.

The Admiralty had had to decide whether the enemy should have full "sight" of the Invasion Fleet, and had decided against it. Hence the terrific jamming of his radar which put it right out of action. This procedure served a purpose other than masking our fleet: it gave confidence to the men of the

mine-sweepers, who were able to tell one another that the enemy could not get his range upon them by radar.

There remained one line of speculative thought, namely, had the enemy anything up his sleeve?

As we know, he had not.

These radar activities, which had so large a part in the success of that great operation, fully justified the years of work since 1940, and was the reward of those who had carried on under conditions often disheartening and never easy.

"PHANTOM"

Control of the Invasion was from a central nerve ganglion in the South of England a hundred feet below ground. From this building millions of words were wirelessed, directing convoys, beach-supplies, men in assault areas, aircraft and ship, big and little.

Between Dunkirk and D-Day there had been no wireless communications, save those of the "cloak-and-dagger" sets, between England and France. But on 6th June, 1944, the two-way signalling never ceased.

The first wireless signal sent from France to England on that day was sent by Phantom, officially G.H.Q. Liaison Regiment. Since the earliest day of the War, this little-known Unit provided fast and accurate information to all branches of the Army. And it continued to do so until the German surrender.

"Phantom" was equipped with Marconi portable sets, and it was from these, used by the 350 officers and men of this Regiment who took part in every major campaign, that these field messages were sent.

During the first days following the landings, Phantom was mainly the means whereby communications were maintained uninterruptedly by the Regiment's patrols. These, armed with their light but powerful Marconi transmitting sets, operated with the U.S. Third, Ninth and Seventh Armies.

WIRELESS WAS FIRST ASHORE

Some time before D-Day, the Company loaned to the Admiralty a number of technicians. They were required for work at an Admiralty Laboratory on mobile equipment designed for the beach landings. And on that day, under heavy fire, the very first equipment to be put off on that beach were two mobile units with small sets designed for the instant establishment of communications between beach-head and beach-head, and beach-head and ship.

This unit was a small van, with sectioned masts for speedy erection. The whole equipment was completely water-proofed—as were the sets supplied for large numbers of jeeps.

Later, these short-range sets enabled shock troops to keep in contact with each other, and with unit commanders, and they, in turn, with off-shore naval units and transport. They were of value also for wireless communications between ground unit and air force to assure tactical air support.

As the battle opened out, the need for wireless communications was, if anything, even more vital. It has been related how, in the early days of the War, and ending with Dunkirk, the Company's *Blue Train* had maintained communications uninterruptedly until the final débâcle.

Now, from the ramps of the landing craft of the Normandy beaches were driven on to French soil the Marconi equipped trailer caravans which were, later, to form the Control Centre of the Second Tactical Air Force operations as we advanced.

THE "BLUE TRAIN" TECHNIQUE

The technique first employed by the original Blue Train was again employed. As one group of trailer caravans moved forward, a duplicate group remained stationery to carry on from the old site, until such time as a new forward park had been formed.

These units consisted of operations rooms, where aircraft courses were plotted, a controller's gallery, planning room, intelligence room and office for Army Liaison officer.

The planning officer worked on target photographs and from wireless instructions, decoding numbers and types of aircraft to carry out the attack, flashing the orders to the airfields where the waiting pilots are briefed.

Thus briefed from the mobile caravan, the pilot takes off. His machine airborne, his course is plotted on an upright glass, his Opes window, which is visible to the operations officer.

By such means the great land battle which developed from the first landings maintained unbroken wireless communications between land, sea and air, and was, as were all the battles and campaigns of the War, made possible only by the perfection of wireless communications.

BUOY-GUIDED SHIPS

It will be remembered that the date set for the Invasion was one based on meteorological records extending over a great many years as that when good conditions might be anticipated with confidence. For days before 6th June, however, the weather conditions continued incontinently bad.

It was in the awkward, choppy sea running throughout the week-end preceding the invasion that a number of fast motor launches carrying supersonic buoys were engaged in laying them off the French shore. They were to guide our ships through the minefields with which the French coastal waters were thickly sown and past submerged wrecks and other obstacles.

By that time the buoys as first used in the invasion of Sicily had been further developed at Chelmsford, particularly in the direction of absolute reliability, the *sine qua non* of an apparatus of this kind. Great pains had been taken therefore to make these buoys absolutely efficient.

For example, the mechanism was so designed that a final test could be made before screwing the top down. No more than that could be done in the place

of manufacture. But one more safeguard was possible, namely, a final test with the buoys submerged and in position.

Therefore when each buoy was laid at its working depth, a hydrostatic switch caused the transmitter to inform the laying vessel—a fast motor launch—that the buoy was well and truly "alive".

For the Invasion, the Mark IV buoy was used, and the meticulous care taken both in design and manufacture then gave a hundred per cent. performance. All buoys laid functioned without failure throughout the great operation.

RADAR OR BUOY?

Now, it may appear curious that the Royal Navy, having the use of radar to guide its vessels in through the minefields off the French shore, elected for the Marconi supersonic buoy.

Two considerations determined that choice, and are of interest.

First, while radar offered complete efficiency, it did not provide the essential secrecy. For the enemy was able to receive the pulses, and thus be made aware of the Armada's approach. The second reason was the circumstance that the Marconi Company's supersonic buoy had already demonstrated its reliability, and thus offered a good alternative method free of the limitation attaching to radar for this particular purpose.

Some weeks after the Invasion an Admiralty officer visited the Company's Works and was brought by its Chairman, Admiral Grant, into the workshops.

There he told the people that the buoys: "Did every single thing expected of them."

Why, again, it may be asked, did his radar not give the enemy full warning of the approach of the great Allied invasion fleet and so enable him to direct his gunfire by radar upon it as it came within range?

"BAGFUL"

The short answer that may be given by the Company through the mouth of any worker who had a hand in that matter would be "Bagful", under which curious code word went the job that produced the device by means of which the Allies were enabled so to disorganise the enemy's radar stations on that day that they were quite ineffective.

"Bagful" was an airborne equipment for intercepting radar transmitters. It was a panoramic recording receiver by means of which a record could be obtained of the frequency of any intercepted radar transmitter.

From markings on the recording gear the airman fixed the time at which the radar station was intercepted, after which, by reference to the aircraft's log, he ascertained his position at that time

The original research on this device was done by the Telecommunications Research Establishment, but the developing, designing and manufacture were carried out by the Company from the rough sketches passed to them early in 1942.

The late President Roosevelt paid a tribute, in his famous speech following

the Invasion, to the part played by this equipment which was in many Flying Fortresses.

"Bagful" was, of course, but one of the many fantastic developments of radar that followed, like a series of miracles or magic, one after another, under the stimulus of war.

It was radar that made it possible for our D-Day bombers to return with the accuracy of homing pigeons, reading their positions on the little gridded map that displayed the signal sent out from the ground station. "Gee", as this system was called, was standard by that date for all bombers, troops carriers and coastal aircraft.

And it was radar that gave to our air crews an instrument that enabled them to ascertain position without sight, and so to rendezvous over targets to precise time-table. Most wonderful of all, it provided the astonishing apparatus where the bomber navigator peered into a cathode ray tube screen and there saw through fog, darkness of moonless night or cloud, as green spots and shadows, the detailed picture of the terrain over which he flew.

What had begun as electronically transmitted information had developed within a few years into visual presentation. Though the disorganisation of the enemy's radar was of outstanding service in reducing our casualties in ships and men to an unhoped for figure, casualties there were.

SERVICING THE D-DAY SHIPS

Early in 1944, the Marine Company was approached with instructions to make ready to handle large-scale servicing and repair work for all types of naval craft that might become casualties in some future action in the waters of the English Channel.

By the end of May, in that year, the Company had established twenty-three bases, extending from Ipswich to Littlehampton. They were mainly designed to service the enormous number of landing craft which were being accumulated for D-Day.

In the event, these bases were little used, for the contingency of a merely qualified success did not eventuate, the first assault being brilliantly successful.

There were, naturally, plenty of "incidents", and for the Company's people servicing the ships, an opportunity to see how equipment stood up to battle conditions.

In one case a mine-sweeper detonated a mine some twenty feet away. The explosion tore the transmitter from its seating and flung it across the cabin. When this craft limped in for servicing it was found that the sole damage done was the destruction of the valves. These were speedily replaced, after which the set was tested and found to be in perfect order.

Even more remarkable was the case of another landing craft damaged by shell fire. When this ship limped in for repairs and refitting it was found that the glass envelopes of the valves had been shattered—but that the filaments were still intact.

VII

THE "BACK ROOM" BATTLE (1)

WAVELENGTHS

Throughout the War there were certain broad trends of research in electronics which were due in large measure to the multiplicity of uses to which electrical apparatus was put. The Services had need of precision instruments for such applications as gunnery control, searchlight direction, for U-boat detection, and for the light, but powerful sets carried by all bomber aircraft.

Greater precision involved improvement in applications of the short-wave technique. It indicated, also, the need for valves of higher power, and of greater sensitivity.

No single concern in the industry was assigned this work by the Government departments occupied with Service supply, for, obviously no single organisation could have handled so vast an undertaking. The urgency was very great, and so a national effort was the only efficient approach, and that meant a pooling of all scientific and technical resources.

To that end Government laboratories and those of the universities and of the industry, were welded into a single, loosely-knit team, often with interchangeable personnel, for the pursuit of this common purpose.

The element of competition, normal in peace, was not eliminated but actually intensified, since it was transferred from inter-industrial rivalries to the bitter struggle for scientific superiority over an enemy scientifically highly endowed.

QUEST FOR SHORT WAVES

Long-distance wireless telegraphy was at first the generalised diffusion of electrical energy on long waves. But the system possessed an inherent defect, regarded from the standpoint of power economy, and had other disadvantages which soon became apparent in practice.

Wireless telegraphy transfers electrical energy from the transmitter to the receiver, agitating the latter and harnessing that agitation to definite signal sounds. The amount of energy required to achieve this object is conditioned by the speed of signalling, and the insulation of the receiver from all extraneous electrical interference, such, for example, as competing signals.

In omni-directional wireless, the electrical energy is radiated in all directions, consequently, as the periphery of the discharge increases, the power becomes progressively attentuated along the swiftly-enlarging circumference. Thus a very powerful transmitter is necessary to compensate for this "wastage", or loss, involved at any direct receiving point.

This is a statement, in simplified form, of the technique where a single transmitter is operating. But the activity of a second, a third or a fourth station, operating the same system, brings into the other picture the factor of selectivity.

Capping X band Magnetrons

Glass Working Department

How, then, does a given receiver identify its own transmitting partner's signals from those of all other transmitters, and so select from the several, the only signal appropriate to it?

BAND WIDTHS

This end was achieved by assigning to each transmitter some agreed portion of the wave-band sufficiently wide to meet the phenomenon of spread of a given wave-length in process of modulation.

The required width of the wave band is determined by the method of signalling and-or speed of the transmission, the higher the speed, the wider the band.

The use of very long waves—10,000 to 30,000 meters—is limited in practice to long distance wireless telegraphy. Medium waves are best suited to broadcasting and short communications. Short waves, with beam aerials, are well suited to long distance communications, and very short waves to aircraft signalling and radar.

The obvious disadvantage of the omni-directional system, was overcome by the introduction of directive beam aerials with reflectors in both transmitters and receivers. By this means the 360 degrees diffusion of the omni-directional method was narrowed to a small number of degrees, with proportionate increase of intensity, the bearing of the receiving station being known.

The advantage of the short wave over the long wave is that it makes more wave-lengths available.

Economy is achieved, then, by lower electrical power and high speed signalling, the increase in the number of services possible on a given wave band, the use of the system for wireless telephony simultaneously with Morse signalling, and, last, for facsimile transmission.

THE MAGNETRON

For the purpose of aircraft location, as it was in 1935, 1,200 cm. wave-lengths did very well; but by the outbreak of the War, new types of valve, capable of generating very powerful radar signals of from 50 cm. to 150 cm., had been successfully designed.

To the Birmingham University Research Group, working under Admiralty direction, belongs the honour of having carried out the research that resulted in the resonant cavity principle used in the Magnetron, the air-cooled valve capable of generating radio energy of many kilowatts on minutely short wave-lengths, which has made centimetre radar a practical proposition.

The struggle for technical ascendancy as between our scientific brains and those of the enemy, became intensified as the undreamed-of possibilities of centimeter radar were gradually unfolded. It had, indeed, the character of a secret battle fought out in the laboratories of Britain and Germany.

The first Magnetrons came into service late in the autumn of 1940. It was then so great a novelty that it was passed round the Great Baddow Labor-

Assembling X band Magnetrons. Control, poise, confidence

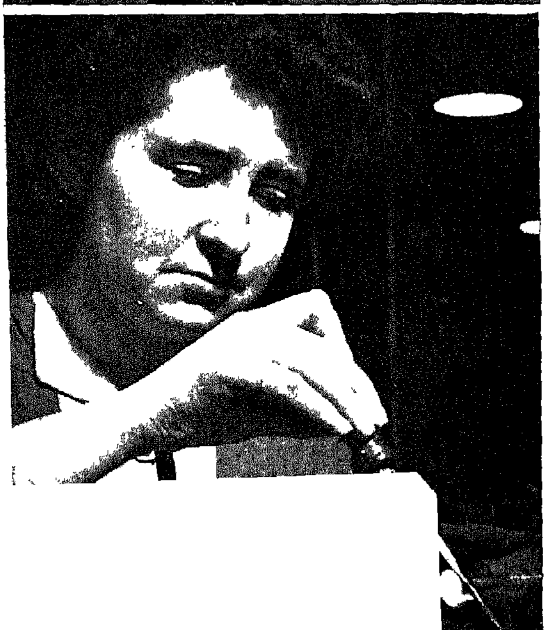
atories like a new scientific toy. The Company's engineers examined and admired this "toy" that was capable of generating radio frequencies at 10 cm. wave-lengths; which could pulse and transmit during a two micro-seconds pulse vast bursts of radio energy and maintain that performance through every five hundredth of a second.

And they told one another that it was the sort of semi-hand-made thing that would be a commercial nightmare under peace-time production conditions.

PRODUCTION DIFFICULTIES

At that time the Magnetron had been put on a pre-production basis by the General Electric Co., Ltd., but it had soon become necessary to extend

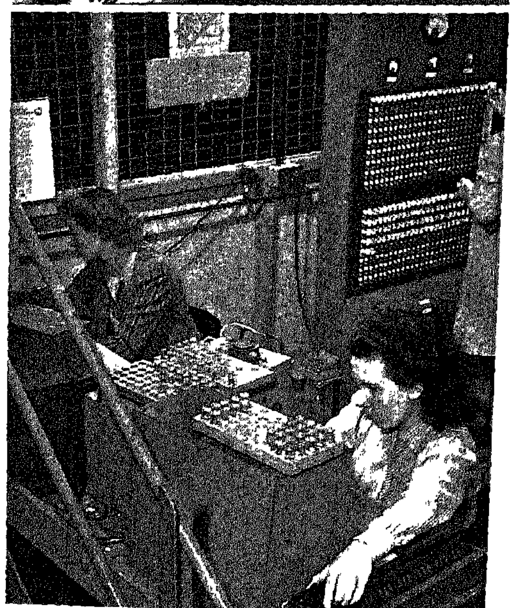
Drill Press Lapping Machine Operator loading lapping mask Note the balance of the two hands

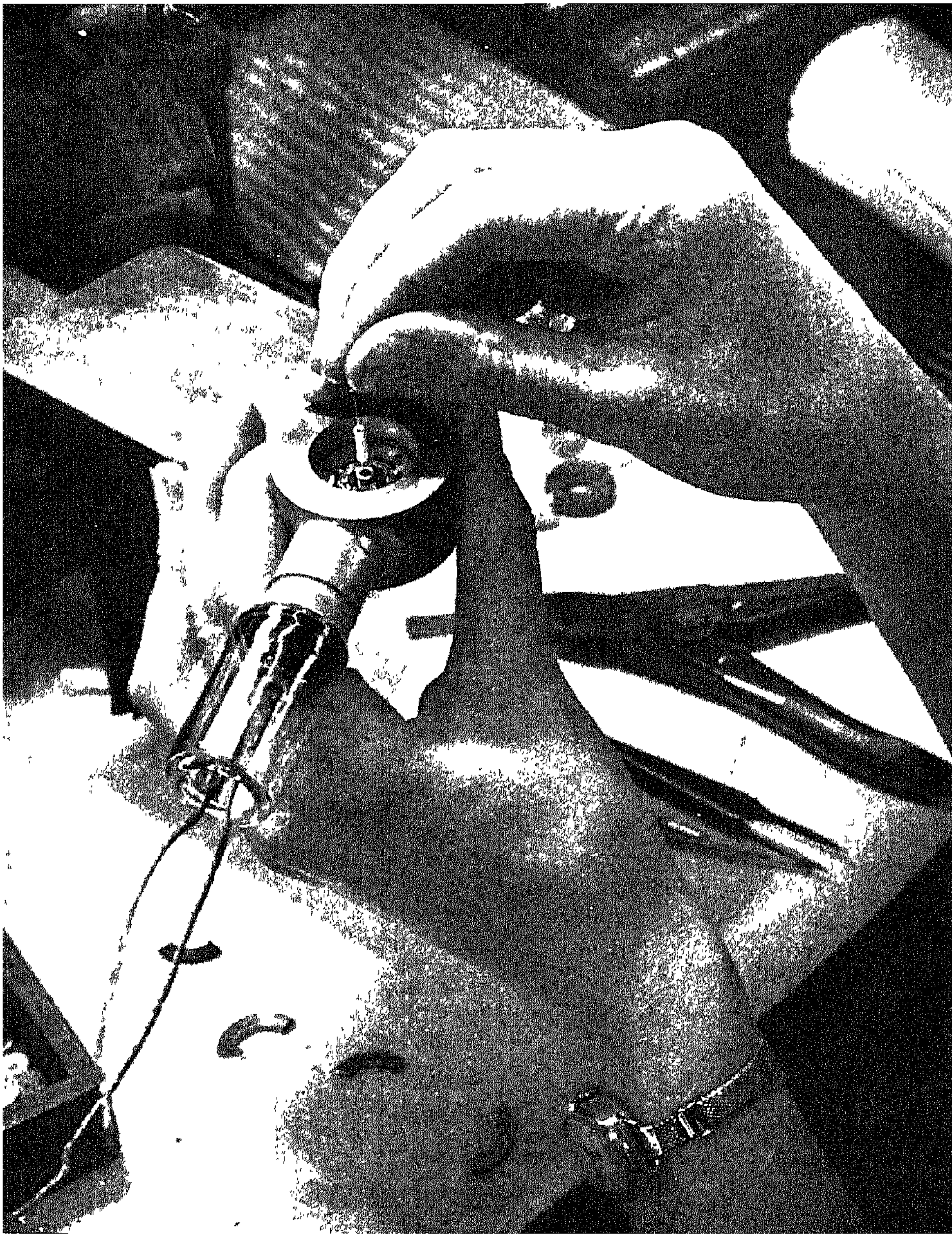


Making copper-glass seals for Magnetrons A most delicate operation

Pumping Miniature Stabilisers

Testing Miniature Stabilisers
A study in concentration





Assembling Heater and Cathode in X band Magnetrons. Skill, precision, beauty

production, and the Marconi Company then began to make its contribution to the enormous requirements of the Services. Work was started at Great Baddow, and by the end of the year about twenty Magnetrons a week were being manufactured.

The difficulties were enormous. A struggle ensued to secure the essential raw materials, tungsten and tellurium copper and so on. But these were either in short supply or defective in quality, or both. This made necessary numerous inspection points in the production line, every single stage of manufacture having to be closely scrutinised.

Though the Company had been supplying the General Electric Company with Magnetron "blocks" which were made under conditions of secrecy, and were thus not altogether unfamiliar with the work, manufacture involved many curious problems for the engineer.

Just as the Magnetron is the heart of the radar transmitter, so is the "block" the framework of the Magnetron, and the whole basis of its operation.

This component involves a number of machine-tool operations carried to fine limits, and in a material not specially well suited for mechanical processing. Even so, towards the peak of the output, the Marconi Works were producing hundreds of "blocks" a week for different types of Magnetron.

The valve manufacture itself threw up a number of curious questions. It is heavy, and yet it has to carry three fragile copper-glass seals through which tungsten rods are sealed. Then copper parts carrying those seals have to be hard-soldered into the "block", and, finally, the whole has to be made vacuum-tight with copper plates and gold washers.

There are thus four types of seal in the Magnetron: copper-copper (soldered), copper-glass, glass-tungsten, copper-copper (gold).

The Magnetron was, in fact, a valve that in normal times would have justified at least a year's further development work. As it was, the Company, in less than a year, was delivering several hundred a month.

Within four months of starting up small-scale production, the Company opened up the new Valve Laboratories in Chelmsford, and there, during the following three years, many thousand Magnetrons were made, the output being several thousands per month.

As time went on, new types of Magnetron were introduced, and the Company was firmly established as one of the three main suppliers.

The great secrecy which was observed in connection with the Magnetron was such that even scrap "blocks" had to be accounted for, and a serial number stamped on every one of them, all duly recorded.

A "JERRY JOB"

One day, an Admiralty officer came by car to the Valve Laboratories, carefully nursing a package.

"We've got hold of a Jerry radar triode" he announced, "But it's a bit the worse for wear. The question is: Can you people possibly reconstruct it?"

The importance of the find was obvious, for to discover the performance of the enemy's radar was almost as important as keeping from him knowledge of the performance of our own.

The reconstruction was successfully carried out and the Jerry radar triode stood on the bench perfect in all its parts. It had been a tricky and difficult job and it had cost about £200.

Before the end of the War, the secret Marconi Valve Laboratory was producing seven types of Magnetron, with a total weekly production of 450 to 500, or about two thousand a month of all types.

Valve development was indeed phenomenal. It was not merely a matter of change in design, for range of application widened in several unexpected ways; while types ranged from elementary components to that masterpiece, the Magnetron.

By the end of the War this Laboratory was producing nineteen types of valve.

HAND AND EYE

At the peak period, 150 women were working on Magnetron production, and 340 in all in the laboratories. They represented a labour élite, for though many were called, few were chosen for this exacting work.

Throughout the War, the Company employed many girls and women called up for National Service. They represented, consequently, a fair sample of the women of the country, since service liability was not affected by economic or social considerations.

There could be no question of selecting the best type of worker for a given job by vocational or other psychological tests: each girl had to be given a trial. The proportion found to be fitted for precision work, whether on the Magnetron, Stabilivolt, on crystal processing, or coil winding, was found to be somewhere between one in five and one in ten.

Two generalisations were made possible on results observed of some hundreds of workers. First, that the age level indicated a progressive decline in adaptability, with under twenty as the optimum age for training. Secondly, that this generalization was not true for girls and women who, in civil life, had acquired manual and visual training.

The best workers from all points of view on such work were the expert needle-women and the professional hairdressers. Both these categories possessed superior dexterity, and a finer sense of timing.

WOMEN AT WORK

Our Valve Laboratories and the works as a whole employed throughout the War girls and women on jobs that formerly were being done exclusively by men in the United States.

From a nucleus consisting of an engineer, a tool-maker and a girl assembler, the practise was to build up from entirely unskilled girl labour a team handling processes ranging from glass-blowing and soldering, to chemical processing of parts, and the testing of the finished valve.

The labour question remained a stumbling block because the valve requires many separate processes of manufacture, and if a skilled girl worker is absent her place cannot easily be filled. Interchange of work was not only difficult, but inimicable to efficiency also.

To watch for a while such work in progress is exciting. A Valve Laboratory is very light and very clean: it has to be. No crude manual operations are performed here, but only those calling for a high degree of skill of hand and eye. The work is intricate, delicate, exacting. . . .

Here at a bench is a slender blonde girl whose poise suggests repose, despite the controlled movements of arms and hands. She is absorbed in the task of setting a minute silverplated copper ring into a milled groove. It is precision work that would have taxed the skill of an eighteenth century watchmaker.

If, standing there, you had asked that girl: "What are you making?" and "What is it for?" she would have replied: "I'd like to know the answer to that one myself."

This imposed ignorance of the nature of the work—working, as it were, blind—had one serious drawback: it removed incentive. The girls neither knew what they were making or the importance of it. Yet secrecy then was essential and had to be maintained at whatever cost.

Let us move along.

Here is a woman intent on heating in CO_2 a ring-fitted copper block. A tiny but intense flame flicks forward, flashes, withdraws like a little snake, and a minute soldering job is done.

Little by little, a Magnetron, that master-key to modern electronic practice, is being articulated.

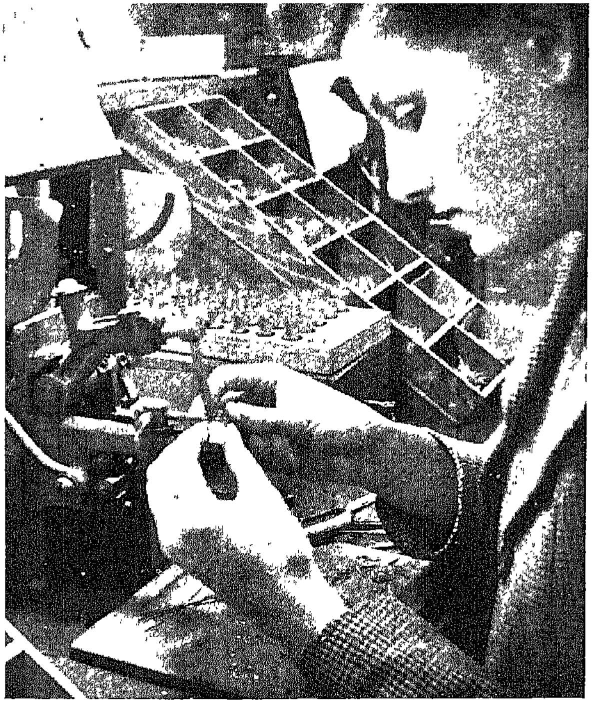
And women and girls are making it; women and girls who, before the War, put their skill of hand and eye into *petit point* or the creation of coiffures, woman's traditional crafts.

THE STABILIVOLT

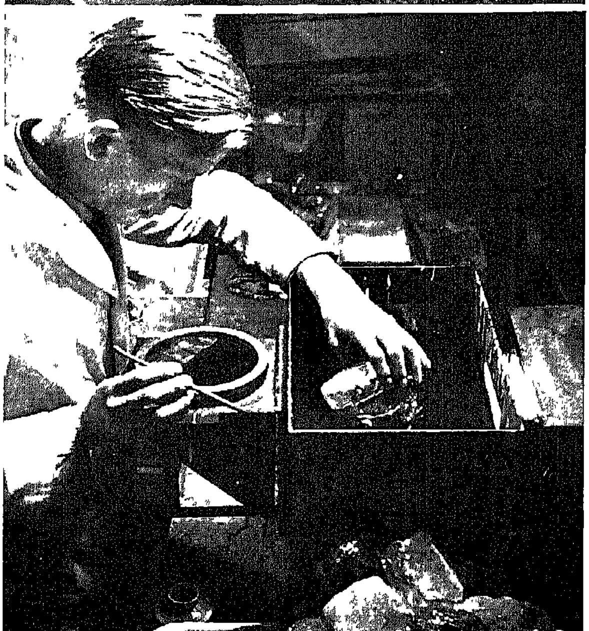
Work on the Stabilivolt was started by the Company early on in the War. The work was new, and the technical difficulties of production were many. It was rather as though a maker of motor cycles were asked to switch over to the making of sewing machines.

Work was begun from drawings passed to the Company by the Marconi Osram Valve Company, which were in turn copied from the German Stabilivolt. There followed a six weeks' struggle out of which came the first very small batch of Marconi-made Stabilivolts.

These were taken by car to London for test purposes. En route, one was



Assembling Miniature Stabilovolts



Z-Axis Determination Bath. Operator about to mark Quartz with Chinese pencil

broken, a heart-breaking mishap, considering the labour that had gone into the work. Under test, it was found that only half the samples were good.

By October, 1941, under the direction of an engineer with thirty girls, many difficulties had been ironed out, and the output worked up to thirty per week under an Admiralty contract.

But far larger numbers were required, and to cope with this demand, work was transferred from Great Baddow to the new secret factory in Chelmsford itself. There, for the remainder of the War, and since, Magnetron, Stabilivolt and valve production has been carried on.

This work was not done as by a shadow factory or daughter company, but by direct contract from the Ministry of Aircraft Production and Admiralty.

There was nothing in the task of making Stabilivolts in itself that was beyond the skill of the Company's technical staff, even in those early days—though both the physics and mathematics of the Stabilivolt remain still to be elucidated.

A CONSTANT FLUX

It was the time factor that interfered with the sequence of orthodox production practice. For production is normally preceeded by a germinal period of experiment. And there was no time for that.

On the one hand were the urgencies of the Supply departments and the imperative needs of the fighting men themselves, two aspects of the same thing, and, on the other, the incredible speed of scientific progress.

An example of this sort of thing occurred in the early days of Magnetron experimental production. Manufacture had begun towards the end of 1942. It started at the 10 cm level. Changes in design were always one step ahead of manufacture, and each change involved engineers' tasks. For instance, jigs and blocks, which had to be changed.

But the biggest step in development was the discovery that if cavities were connected the efficiency and frequency stability could be improved, and that strapping would enable the Magnetron to be run on higher power without changing wave-length. Thus it was that the Company had to produce a type already obsolescent, with its successor already on the bench.

Stabilivolts were needed, above all, for our fighter aircraft, and, somehow or other, they had to be produced. And produced they were, more than 350,000 of them.

Throughout that period work continued day and night unceasingly.

CRYSTAL STABILIZERS

To-day, piezo electric crystals are used mainly for stabilizing the frequency of transmitters, for narrowing the bands in receivers, and in all precision-measurement apparatus where a frequency control is essential.

The *Gee* system, in which time differences in the receipts of signals from three or four stations are used to fix the position of the receiving station, is made

possible only by the crystal component. It was this system which made it possible for our bombers to assemble over their targets in saturation strength to a perfect time schedule.

Very early in the War, Service sets were either converted to, or replaced by, crystal-controlled sets. Thus, at once, a very large demand for crystals was created, producing a reflex on the industry that was expected to produce them.

It was not a question of thousands, but of millions of crystals, and so a new field of experiment, organization and production was opened up.

The Company had been pioneers in the use of Piezo Electric Quartz for the frequency control of high-frequency oscillators. In 1926, a crystal for a frequency of about 94 kcs. was cut by hand, a job that took a complete working week. Development and application were continuous, and by 1931, the broadcast transmitter was fitted with a zero temperature co-efficient crystal which was the first of its kind in Europe. This station was in the Marconi Works and was operated by the Company for the B.B.C. Two years later, some twenty-two European broadcasting stations were fitted with crystals, and so real frequency stability was virtually achieved.

Much original thinking made this pioneer work the success it was.

And so often during those years of difficulty and strain, there were set-backs, and disappointments before smooth-running crystal laboratories and workshops were happily stepping up production to the million mark.

In 1942, a separate Department was set up to deal with the enormous increase in the demand for crystals. And this was something the Company had not, and could not have foreseen.

Its pre-war crystal manufacture had been carried out under laboratory conditions unfavourable to mass production; and it was mass production that was now demanded of it.

Again, in those early years it was sufficient to have on this work one engineer, giving, perhaps 20 per cent. of his time to it, supervising a staff of no more than three.

Now the Department had a mushroom growth which at the peak of output employed over two hundred people, spread over two shifts, twenty hours a day, six days a week.

QUARTZ

Brazil supplies the world with most of the quartz used in this work. It is a precious stone, almost water-white, and it comes in lumps ranging from 500 grammes to 10 kilogrammes. A lump of mother crystal, weighing about 28 lb. may cost £300 or more. During the War forty tons of quartz was consumed in the Marconi Quartz Laboratories, at a cost of £400,000.

In its perfect state, quartz is well-faced and facetted and as white and transparent as glass. But not all quartz comes perfect to the inspection bath that will fix optical axis and launch the mother quartz on the considerable journey

Setting Mother-Quaitz in plastei of Paiis

Final Etching process of Crystal plates

through the large, light and clean laboratories, to finish up as thousands of exquisitely-wrought plates, some far thinner than the paper upon which these words are set down.

THE CRYSTAL LABORATORY

Nearly all the operations to which the crystal is subjected in the laboratory are done by women and girls. Here you may watch deft hands clip crystal in jig, fix in plaster of Paris, and cut, watching behind the protective glass-screen the whizzing diamond studded copper wheel as it slices that crystal as a grocer slices ham.

"When we started" explained the Engineer in charge of this Department, "it took as long as an hour to cut through one square inch of the material. Now it takes only fourteen minutes, and during 1944, 1,056 square inches of quartz was cut for every minute of working time throughout that year."

The cut is complete. How thick? At this stage, perhaps half an inch, or, maybe, an eighth.

And now, the raw quartz cut, a deft hand slips it in position for x-ray test, then on it passes, etched by acid, to be ground and polished.

That original lump of quartz has now lost entirely its identity and has become a large number of one-inch crystal plates. Like a dealer handling cards, a girl operative places some sixty of these tiny crystals on a circular plate. She turns a switch and watches, absorbed, as the plate revolves. Presently she will stop the machine and examine those sixty plates. And she will ask herself: Are they of the right thickness? That is, to an accuracy of a one-thousaneth of an inch.

"That you would say, is skilled work" remarked the Engineer. "And you would be right. Yet, because we are in a non-industrial area we had great difficulty in getting skilled male labour, for the Lense trade have absorbed all skilled optical workers, and so we had to make-do with an 85 per cent. dilution by female labour.

"What were these girls like?" the Engineer cast his eyes over the large Laboratory, with its rows of benches and quiet, preoccupied girl workers.

"They are keen and enthusiastic. I tell them, whenever security permits, what the crystals are needed for, and how important their work is. And then nothing could exceed their high standard of work and courage and fortitude."

"Fortitude?"

"Yes, fortitude, for it takes that to leave this village laboratory in fog after a heavy day's work, to find the bus services off *and to walk as many as thirteen miles home, and yet turn up next morning and clock in on time.*"

Here, as in the great Instrument Shop, one receives the impression of a good team spirit between those who control and those who carry out the work designed.

"The technical skill attained by these girls," the Engineer continued, "has been remarkable, particularly when you remember that in this industry

directing officials must be fully-trained engineers who have, further, specialised in crystallography."

"How was it done?"

"By breaking down operations and singling out certain girls with proven ability, so that little nuclei of workers who vie with each other for the best product and the greatest output, were built up."

ACHIEVEMENT

There is no waste in this Laboratory: it has been eliminated. Between raw quartz and the final product, there is only a residual swarf.

Final Frequency Test Point. Operator measuring Frequency. Delicacy of touch, close attention, perfect hearing.

H

There were two periods during the War when the crystal workshops and laboratories had to stand up to "crash" jobs. The first was when Russia called for a large number of the small and portable receiver and transmitter sets.

The number available for the first convoy, which it was regarded as imperative to catch, was governed by the output of the crystal Department—few crystals, few suitcase sets.

At that period, the work was not as yet at full production stage; yet 25,000 crystals had to be forthcoming, a quite unreasonable demand.

"The position was explained to the girls," said the Engineer, "and the result was that before we were through they had to be ordered out of the laboratory."

Within a week, working at full stretch, production was stepped up to six hundred a week, and the asked—for number of sets were swung into the waiting holds of the first Arctic Convoy in due time to be dropped with the Soviet paratroops into enemy-occupied Soviet Russia.

The other occasion was shortly before D-Day. This time the demand came from the Admiralty, and was even more onerous. But by that date the Crystal Department had found itself. The weekly output had become stabilised at around the one thousand five hundred mark. In response to the Admiralty's call, that figure was doubled, and a 3,000 per week output was maintained until the necessity for so high a figure had passed.

A GOTHIC SET

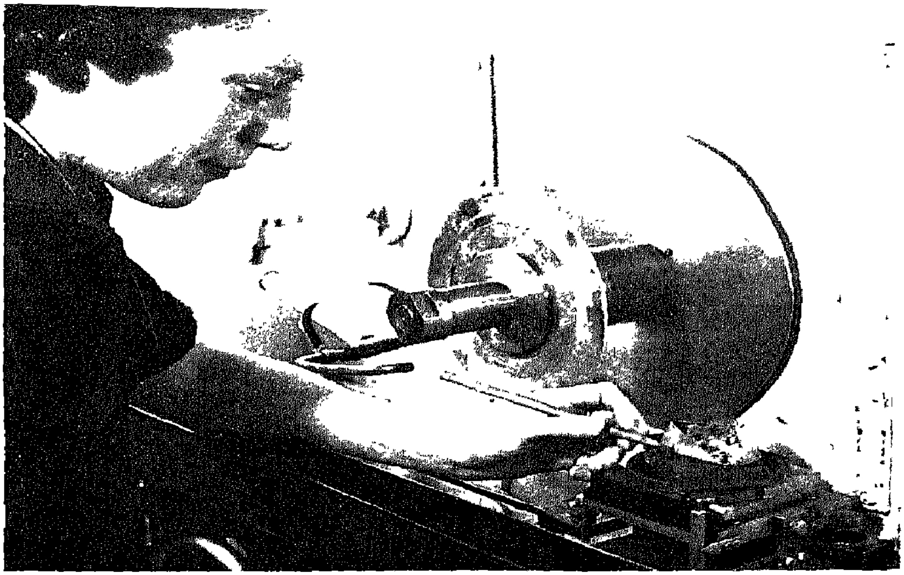
Ever since the very early days the Marconi Company—the first broadcasting organisation—has been closely associated with the B.B.C. as supplier of wireless apparatus, and in particular, of transmitters.

When war broke out it brought unprecedented opportunities for propaganda by way of the ether, and Langham Place was soon a polyglot world voice that was never once silent, day or night, throughout the war years.

Early in 1940, when the call for additional apparatus to cope with the new activities of the B.B.C. was pressing, the Company received an urgent request for a 2 kwt. transmitter. There was no time to put the work through the usual channels of production and consequently a set was assembled in the laboratories of the Development Section from existing stocks of materials and experimental components originally intended for other purposes.

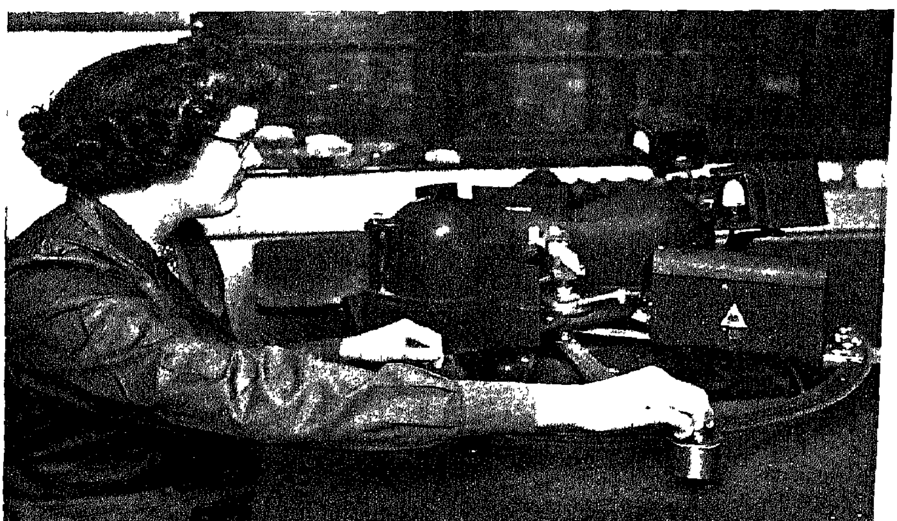
The transmitter was eventually housed in a curious-looking wooden frame-work somewhat resembling a model cathedral, and soon after its delivery to the B.B.C. it was christened the Gothic Set, by which name it is still known.

During the War, more than half all additional transmitting apparatus used by the B.B.C. came from the Marconi Company. It included super transmitters in parallel, twenty in all, medium and short wave, erected at Droitwich, Start Point, Hull, Penrith, Redruth, Burghead and Lisnagarvey.



Quartz Cutting Machine. Operator making identification mark before X-ray measurement

Making X-ray measurements on Quartz strips



MARCONI INSTRUMENTS

At the outbreak of the War, Marconi Instruments had been established for three years, its business mainly the manufacture of communications test gear.

War at once widened the character of the Company's products, as it increased greatly the demand for them.

Work was at once dispersed to minimise danger from the air, one production unit being set up at High Wycombe and other premises being taken over at St. Albans. Here were housed administrative staffs, development laboratories, service departments and two manufacturing units.

The first big orders were for signal generators for Service use, and, later, these were adapted for radar. Subsequently, signal generators were developed for H.F. with a range extending to 300 Mc/s.

The variety of instruments made during the War years was remarkable. It ranged from Service requirements to government laboratory equipment and even included apparatus of a very specialised kind.

For example, despite preoccupation with the big flow of war material, the Company was able to produce and even to improve upon a number of highly-specialised electro-medical instruments.

There is an instrument that sometimes comes before the public eye during criminal proceedings where the defence set up is that of epilepsy. In such cases judges are now becoming familiarised with the Marconi Four-channel electro-encephalograph. By means of this remarkable scientific instrument brain impulses can be recorded.

To this instrument, the subject gives a negative or positive epileptoid reaction, upon which may depend the issue of criminal responsibility for major crime, including murder.

In this instrument the Company demonstrate the wide and often perhaps unexpected applications to which electronics are being put to-day.

It is a reminder, too, that the Marconi Company, for six years engaged enclusively on the design and manufacture of war materials, was originally concerned with the application of science to the purposes of peace, and that now, the war over, it resumes that normal course once more.

VIII

THE "BACK ROOM" BATTLE (2)

"*THE JOB IS ON . . .*"

At 9.30 a.m. Tuesday, 1st August, 1944, twelve senior members of the Company's staff met in Room 200, Marconi House, Chelmsford.

They took their seats round the table and at once addressed themselves to the matter in hand. In a word, it was: How best to attempt a job that, on the face of it, appeared to be well-nigh impossible, owing to the time limit imposed?"

This was by no means the first occasion when such conferences had been held in that room during the War years. They had come at intervals, and each time with a challenge to the resources of the Company, and to the ingenuity, determination and capacity for brilliant improvisation of its technical and scientific staffs.

Each "crash" job brought difficulties peculiar to itself. Now what was wanted, and wanted in the most urgent way, was a certain type of transmitter for jamming the enemy's radio; and the call was for large quantities, not of the standard equipment, but that equipment modified for a special purpose. And all this within a drastic time limit.

It was estimated that the work indicated a seven-months programme, even as a war-urgency job. And the question was: Could so big an undertaking be completed *in a matter of weeks*?

That was a time of greatest anxiety, of immense strain, and these men went into the "back-room" council of war very conscious of their responsibilities.

There then ensued a rapid-fire exchange that shuttled back-and-forth somewhat as follows:

"The job is on."

"I'm prepared to clear eighty per cent. of the modifications by Wednesday morning. In fact, I could release a number of parts practically immediately."

"We'll fix four working teams in parallel."

"I'll place an order on the factory for sixteen installations."

"What about existing contracts?"

"Ignore them."

"I've all necessary parts for completing three modulators, and I've other modulators well in hand."

"So far as the shops are concerned, I'll clear the lot by the end of the August Bank Holiday week."

"We must investigate the valve supply."

"And the vacuum condensers."

"We'll have to contact the Admiralty as to whether they'll need aerial supplies, too."

"We must fix the Ministry of War Transport for priority authority."

"We'll probably have to supply installing engineers—we'll assume that, anyway."

"Then draft suitable engineers into the testing department and get down to the details of the job. . . ."

Throughout the War, the method adopted by the Company remained constant, it may be summed up as organisation, plus team work. There were no "stars" and there were no medals.

In this particular case, the last of 150 transmitters left Chelmsford Works precisely seven weeks after the meeting described above. And it came as near to the performance of the impossible as any "crash" job rushed through under high-pressure, day and night, during the War.

At the conclusion of this job the Chairman, Admiral Grant, gave the traditional naval order to all concerned, namely, to splice the main brace.

V.II

Secrecy was maintained at a very high level throughout the War, and sometimes in a manner that was slightly disconcerting to those had had to bring a scientific contribution to some secret purpose.

In August, 1944, the much-tried people of Deal were puzzled by the sudden appearance in their midst of cavalcades of lorries and service cars. They were even more perplexed as they saw a mushroom colony of hutments go up, as it were, overnight.

What was it all about?

There were many highly-trained technicians at work in those huts, supervising and erecting radio equipment, much of it very heavy material. Yet not one of those Marconi men had any more idea of what it was all about than the good folk of an old coastal town.

What they did know was that the whole resources of the Company were being focussed on this job; that they had to instal sixteen transmitters, working round the clock; and that these transmitters, standard S.W.B.II. 8 kilowatt Marconi equipment, had been reconditioned and adapted to some secret purpose.

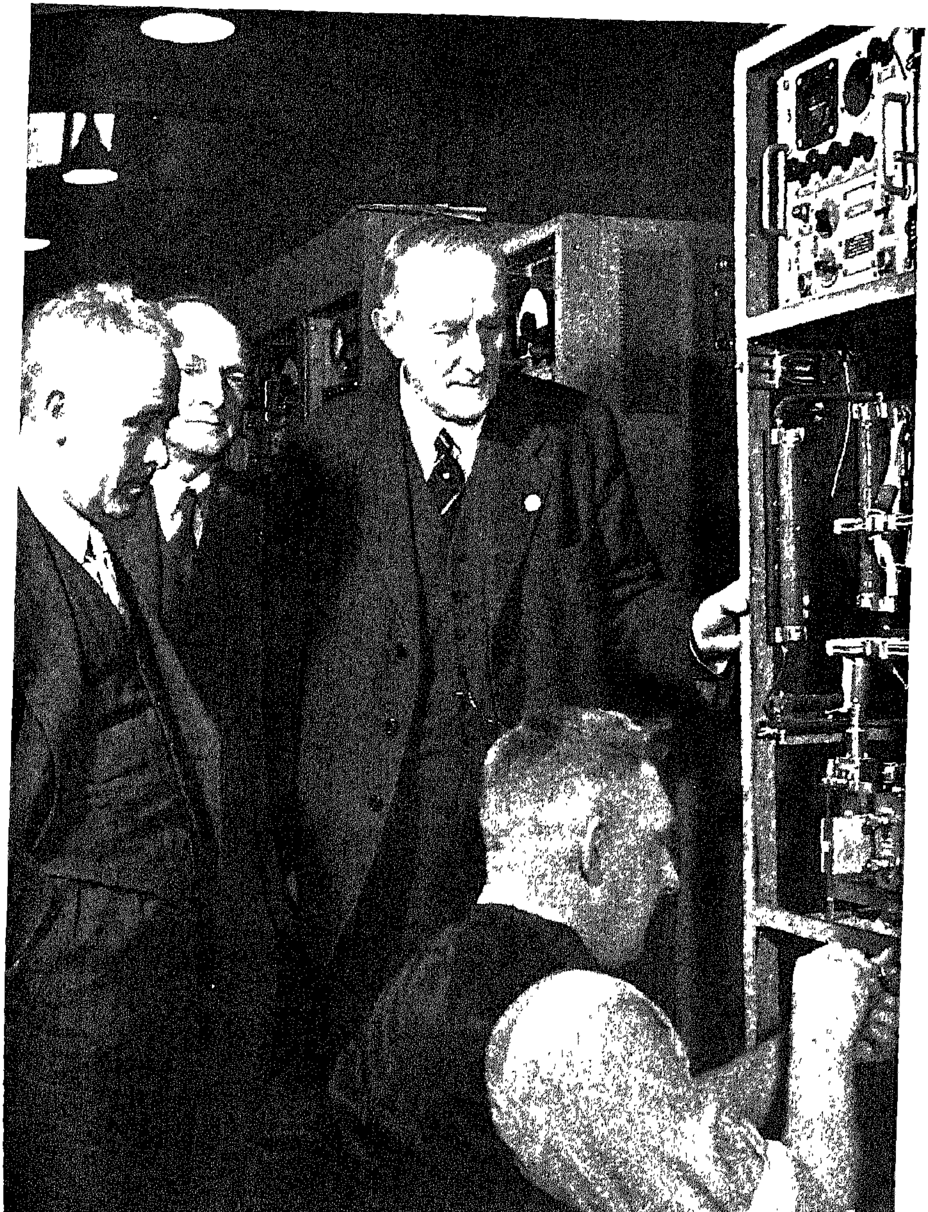
It was exhausting; but it was exciting, too.

It is permissible now to tell the story which the reader glimpsed at its first chapter in Room 200, Marconi House, and, in its second, just outside the ancient Cinque Port.

Told, also, may be the reason why, after all that feverish endeavour, that radio station was never used against the enemy.

ROCKET SECRETS

Long before the first rocket added a new note of frightfulness to the War, our Intelligence people had been patiently gathering information about Germany's rocket experiments.



The Chairman watches Operator assembling 960 Modulator.

It was known to the Cabinet that the Germans were trying for a 90-120 ton rocket, and many details of the actual design were also in the hands of the government experts.

Certain facts had been definitely established. First, that the rocket was radio-controlled with the double purpose of steering it upon its course, and detaching the war-head at the moment for detonation.

It was known that two different wave-lengths were used for those purposes, and it was decided that we could jam this radio control from the English side of the Channel.

The type of rocket devised and developed by the Germans had an exceedingly high velocity, and our scientific people had good reason to believe that the radio control was effective only for fifteen seconds after the firing of the projectile, after which the receiving mechanism went out of control.

This mechanism served to steady the rocket on its course, and the transmission had to be on definite frequencies. These frequencies were unknown to us. But we did know the approximate wave-length, though that, in itself, was not enough. What we had to do was to pick up the signals sent from ramp to rocket, and to measure the wave-length. Then, having that datum, to send counter wave-lengths out.

But here was a technical problem. The rocket knocked out of its course, it remained to detonate the war-head.

This proved to be a real teaser, posing more than one thorny technical difficulty. One day, perhaps, this unwritten chapter of the War may be written, but at this time of writing it must remain, with much else colourful and romantic, unrecorded.

In the event, other factors changed the situation and much labour was thus lost.

Work on transmitters and modulators was still being pressed forward feverishly in the power-testing department of the Marconi Workshops in Chelmsford, when the familiar spare figure of the Chairman, Admiral H. W. Grant, was observed advancing with upraised arms.

"Gather round!" he shouted. "Gather round!"

Admiral Grant has a way of giving whatever he does a naval tang, perhaps natural in the son of an admiral; and for him the Company's people have always been his "ship's company".

Now he boomed: "Cease Fire!"

It was a dramatic moment, and the first reaction was the natural one that the War was over, whereas, this was the "Cease fire" for that particular "crash" job only.

The mass of costly equipment assembled at various points, and at Chelmsford, was never used, and for the simple reason that, if the War was not over, we had at least beaten the enemy, and with the overrunning of his rocket ramps, had banished this particular horror from the skies.

YALTA

On 6th January, 1945, the SS. *Franconia* berthed at Liverpool docks.

The moment she tied up, and before even the Customs men had got aboard, a civilian, who had been waiting on the quay, dashed up the gangway followed a few moments later by a party of workmen.

He had travelled to Liverpool from Chelmsford, this Marconi engineer, at a moment's notice, and with verbal instructions to instal two transmitters in the *Franconia*, and to get the job finished in ten days.

As it represented a fair four-months' job, even with such advantages as drawings and proper layout, the importance of this ship's secret mission was obvious.

In addition to this installation of transmitters, the verbal instructions, which were all the engineer had, called for the installation of two power plants complete with Diesels; and, last, for the sound-and-fire-proofing of the whole job.

The smoking room, having been chosen as most suitable for the installation, its fitments and furniture were at once stripped and removed with the single-minded thoroughness of a horde of locusts by the first workmen aboard, who were followed shortly by a battalion of charwomen.

Night and day, for ten days, drawing labour and materials from almost every ship in port, and side-stepping all difficulties and obstacles with the help of the Marconi Marine Company's Liverpool Depot staff who knew the docks thoroughly, this wide-open job was completed in the ten days set for it.

It was a feat of physical endurance in arctic weather, and a triumph of engineering improvisation, which included, among other feats, the acetylene cutting of the ship's hull for the passage of the one-ton transmitters.

While this installation work was proceeding, the ship's "A" deck was also undergoing a transformation. Costly furnishings, including a grand piano, were slung aboard, and magnificent tapestries were hung on the walls. An ultra-modern cocktail bar was fitted out, complete to the last detail, and a suit of rooms was prepared for the "Unknown", the V.I.P. for whose transport, clearly, the ship was thus feverishly being fitted out.

When the SS. *Franconia* left Liverpool for an unknown destination, she had aboard two hundred V.I.Ps, with their large secretariate.

The day before the sailing, the Marconi engineer, who sailed with the ship, was asked by a grinning stevedore where the ship was bound for: "Going to see Uncle Joe, Mate?" he suggested.

That is how secret it had all been: nobody spoke, yet all knew.

At Yalta, for the fifteen days of the Big Three Conference, a twenty-four hours telegraphic communication with the Admiralty in Whitehall was maintained on at least one frequency at a time, and sometimes on two, at a speed of three hundred words a minute.

The record achieved was nine minutes between receipt of message aboard at Yalta and the receipt of the final message back to the ship from London.

In all, 240,000 groups (i.e., of five letters) were handled.

MR. CHURCHILL SAYS: "THANK YOU"

Towards the end of the Conference, Mr. Winston Churchill for whom, of course, the ship had been prepared, but who had at the last moment decided to fly, came aboard.

He said, addressing the ship's company:

"You carried here and accommodated signals personnel and communications which have made it possible for me and my advisers to keep in constant touch with the progress of the war and to keep His Majesty's Government in London informed of the progress of the Conference."

At a later date, the Chairman of the Company received a letter from the Controller of the Navy, Sir Frederick Wake-Walker.

"You will remember," he wrote, "that it was necessary recently to ask you to fit 2 S.W.B.88 Transmitters and other equipment in the SS. *Franconia* as a rush job. I have been informed that the work was completed in time, thanks largely to the splendid efforts and co-operation of your staff, and it gives me great pleasure to pass this information on to you. Now that the ship's duty had been fulfilled, I can tell you that the equipment your men installed carried the whole W/T traffic of a British Mission of the highest importance without any appreciable hitch or delay, for this we are very grateful."

The Lord Mayor of London comes to look

WORK, WAR AND HEALTH

In an earlier part of this brief record of the Marconi Company's life and work during the years 1939-1945, it was observed that the basis of the Company's work is scientific research. That is true, but not the whole truth. At any time, and in particular when war imposes its terrible stresses and strains on the human nervous and physical organism, the quality of labour is conditioned by the health and general well-being of the worker. And no Company which ignored that fact could hope to secure from its people the best unless, on its side, the management took thought for that well-being.

The Company has always had a Welfare, First-aid and Hospital organisation, and early in the winter of 1940 was taking steps to maintain the general health of those it employed. From that time forward halibut-liver oil was made available to all employees. Throughout the whole War period, the Company's people maintained a very high standard of general health, and the freedom from common colds was attributed to the prophylactic measures taken.

But men and women are not machines to be oiled only in order to secure good work. Into the complex come other factors, among them the psychological.

One of the oldest foremen in the Company's service, a psychologist all un-

A Shorthand Typist

An Executive's Secretary

awares, for it is doubtful whether he would know precisely the meaning of the term, made a very significant remark in this connection. He said: "When I saw a man packing up through being on the go for longer than he could stand, and when I knew I had to squeeze just a bit more out of him, I used to say 'Clear out and have a bite and a cup of tea'. And, sure enough, in half an hour he would come back, spit on his hands and go to it."

The well-established fact that the fatigue factor impairs efficiency; and the equally well-attested fact that even minor maladjustments at desk or bench, produce not only physical, but emotion reactions (e.g., irritability) are recognised as practical matters to be eliminated by good arrangement of working material and lighting.

Throughout the War the fatigue factor was met by the periodic rest interval, the Company providing Rest Rooms, trained nurses, day and night, to deal with illness or accident, and adequate medical supervision.

Artificial daylight lighting eliminated that common cause of industrial strain, bad lighting, and good factory, workshop and laboratory lay-out yielded maximum comfort for those using them.

Taking the average figures for the country as a whole, the Company's averages for illness and absenteeism are low. They compare well with plants situated beyond Bomb Alley, and were unaffected by the calamitous bombing suffered by the Company as described in an earlier page of this record.

Good light, warmth, ventilation, these are all-important for the production of maximum results. So, too, the introduction of "Music While You Work" was found to provide a stimulus measurable in relation to output.

Of industrial diseases, only one made its appearance, namely, skin disease. There was, of course, a general rise in skin diseases throughout the country during the War. This has been attributed to lack of fats and the resultant dryness of the skin.

In factory operations involving industrial oils, the fat-starved skin absorbs both oil and dirt. It was mainly on this part that such skin diseases as made their appearance during the War occurred.

But so few were the cases that the Inspector of Factories made an enquiry into the matter. The conclusion reached by him was that the low incidence of these and similar deficiency or industrial diseases was due to the quality of the welfare arrangements made by the Company. In these Mrs. Grant took an active interest, in particular with regard to hospital cases.

L'ENVOI

This brief record of the work of the Marconi Company between the years 1939 and 1945, is, in some sort, the picture of a great scientific undertaking as harnessed to the purposes of total war.

But unless there has been communicated to the reader something more than that, then it has failed in its purpose.

For this great undertaking, that deals not only with the materials of Vulcan's Forge, but in the mystery and magic of the lightnings of Jove, is more than the sum of its material parts. . . .

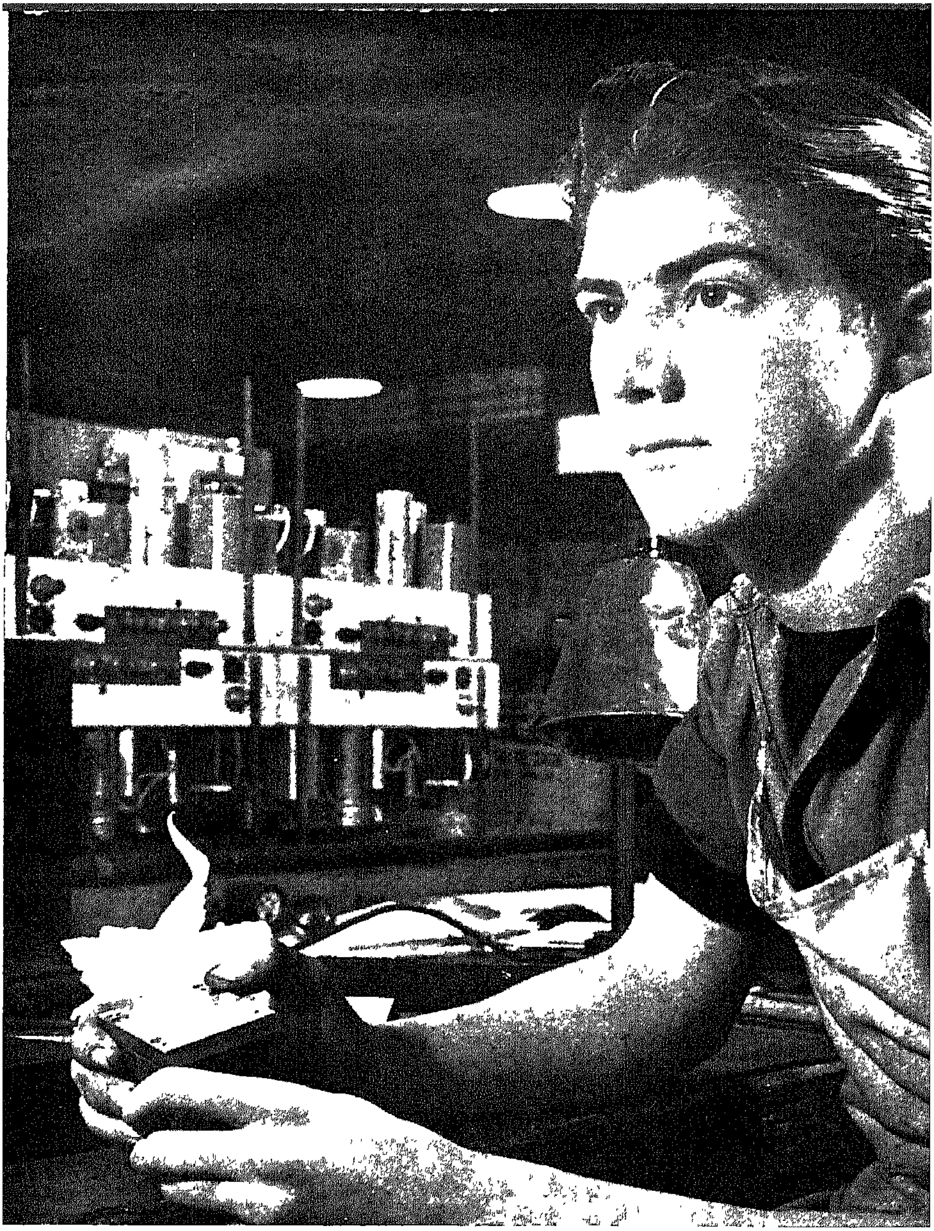
A research engineer, walking in the soft sunshine on the little lawn beside Marconi College, and looking back over the feverish years now closed, was trying to explain this thing.

He paused, considered for a moment and then said, as one who states an objective scientific fact:

"It is, I think, that the Marconi Company has a *soul*."

The active-service pictures in this book illustrate the manifold uses of wireless in war. They do not, in every case, show Marconi Company apparatus.

YOUTH
He serves afloat . . .



YOUTH
he serves ashore

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